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POWER TRANSMITTING MECHANISM.*

ON THE STRENGTH OF THE TEETH OF WHEELS.

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The object of this paper is to correctly report the existing rules and formulæ for the strength of the teeth of wheels, to give all definite statements of the experiments upon which such rules are founded, as fully as the limited records at command permit, and, finally, by the use of like dimensions, to work out an example by each of the several formulæ for the practical end. The example chosen for this purpose is considered to be a fair one by several writers on this subject.

In order to present in each rule the same general form, which is adopted for ready reference, and at the same time to not affect the integrity of its purpose, the notation has been changed to the initial letter of the part specified, and written rules agreeably to the above have been converted into formulæ.

This method of presentation has been selected to show at a glance the precise elements of the wheel which enter into the make-up of the rule, and to give the result of each rule after complete working out of the conditions named.

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Notation.

The same letters refer to like parts in each formula.

Let p = pitch of teeth in inches.
t = thickness " "
l = length " "
f = face " "
L = length of teeth in feet.
d'' = diameter of wheels in inches.
d = " " in feet.
n = Rpm. = rev. per min.
v = Fps. = velocity of pitch line in feet per second.
v' = Fpm. = " " " in feet per minute.
H = horse-power transmitted.
S = stress on teeth in lbs.

Each formula is solved by the introduction of the following elements: the results are placed in the 4th column and show plainly the values of H and S according to each authority.

$p=3''$; $t=1{\cdot}38''$; $l=2{\cdot}1''$; $f=7{\cdot}5''$; $d=5'$; $n=60$; $v=15{\cdot}708'$; $t = {\cdot}46$ p; $l = {\cdot}7$ p.

Table I.

From Bourne on "Steam Engine."

No.	Authority.	Formula.	Horse-power.
1	Boulton and Watt,	$H = \frac{p^3 \times f \times d \times n}{306}$	66·17
2	Carmichael, 1814, copied by Grier and Templeton,	$H = \frac{t^2 \times f \times v}{2{\cdot}27\ l}$	47·06
3	Stripe,	$H = \frac{t^2 \times d'' \times n}{100}$	68·56
4	Tredgold,	$H = \frac{p^2 \times v}{1{\cdot}75}$	80·78
5	Farey, 1827,	$H = \frac{p^2 \times f \times d \times n}{240}$	84·37
6	Hick,	$H = \frac{p^2 \times f \times v}{16}$	66·27
7	Roberton, 1814,	$H = \frac{t^2 \times f \times v}{4}$	56·09
8	Glasgow Practical Mech'c,	$H = \frac{p^2 \times v}{2{\cdot}5}$	56·55
9	" " "	$H = \sqrt{\frac{p^2 \times n^2 \times f}{4{\cdot}5}}$	73·49

No.	Authority.	Formula.	Horse-power.
10	Buchanan,	$H = v\left(\frac{t}{\cdot 75}\right)^2$	53·18
11	Fairbairn,	$H = v\left(\frac{t}{\cdot 587}\right)^2$	86·75
12	"	$H = \frac{t^2 v}{\cdot 344}$	86·96
13	Box,	$H = \sqrt{dn} \times p^2 f \cdot 043$	50·27
14	Molesworth, 1875,	$H = \cdot 06\, p^2 v f$	63·62
15	D. K. Clarke,	$H = \frac{p^2 d n}{58 \cdot 3}$	46·31
16	Nystrom,	$H = v\left(\frac{t}{\cdot 663}\right)^2$	67·96
17	" 1854,	$H = \cdot 614\, p^2 r$	86·8
18	" "	$H = 2 \cdot 9\, t^2 v$	86·75
19	" 1875,	$H = \frac{t f v}{\cdot 55}$	295·59
20	" "	$H = \frac{p f v}{1 \cdot 2}$	294·525
21	Jones and Laughlins,	$H = \frac{p d'' f n}{550}$	147·27
22	Haswell,	$H = v\, t^2\, 5 \cdot 45$	163·
23	"	$H = v\left(\frac{t}{\cdot 465}\right)^2$	138·23
24	Engineer and Mach. Ass't,	$H = \cdot 4\, p^2 v$	56·55

Table II.

No	Authority.	Formula.	Safe stress in lbs.
1	Tredgold,	$S = 138\, p f$	3,105·
2	Engineer and Mach. Asst.,	$S = \left(\frac{p}{\cdot 0517}\right)^2$	3,364·
3	Morin,	$S = \left(\frac{t}{\cdot 025}\right)^2$	3,047·
4	Tredgold, quoted by Rankine,	$S = 1500\, t^2$	2,856·6
5	Rankine, 1869,	$S = 160\, p f$	3,600·
6	Engineer and Mach. Asst.	$S = 1600\, t^2$	3,047·
7	" " "	$S = \left(\frac{t}{\cdot 025}\right)^2$	3,047·

No.	Authority.	Formula.	Safe stress in lbs.
8	J. G. Lawrie,	$S = 510\,p\,f$	11,475·
9	W. C. Unwin,	$S = 200\,p\,f$	4,500·
10	F. Campin,	$S = \frac{1333\frac{1}{3}\,f\,t^2}{l}$	9,068·6
11	Box,	$S = \frac{t^2\,f\,600}{l}$	4,081·
12	Imp. Journal,	$S = 1576\,t^2$	3,001·3
13	D. K. Clarke,	$S = 900\,t^2$	1,713·96
14	"	$S = 180\,p^2$	1,620·
15	Haswell, 1860,	$S = 135\,p\,f$	3,037·5
16	" 1868,	$S = \frac{720\,f\,t^2}{l}$	4,897·
17	Nystrom, 1854,	$S = 1600\,t^2$	3,047·
18	" "	$S = 300\,f\,t$	3,105·
19	" 1875,	$S = 1000\,f\,t$	10,350·
20	" "	$S = 460\,p\,f$	10,350·
21	"	$S = \frac{150\,f\,t^2}{L}$	12,242·57
22	Haswell,	$S = 3000\,t^2$	5,713·2
23	"	$S = \frac{V f t^2}{L}$	4,897·
24	J. Christie, 1877,	$S = 462\,p\,f$	10,395·

Notes on Table I.

Formula 2. "The rule given by this authority is $\frac{t^2 \times f}{l}$ at 2·27 ft. per second; but we have altered it to be applicable to all velocities: $p = 2{\cdot}1\ t$; $l = 1{\cdot}2\ t$; $f = 4\ t$."

Formula 6. "This rule is $\frac{p^2 \times f}{4}$ at 4 feet per second. We have altered it for all velocities: $l = \frac{7}{12}\ p$.

Formula 7. "This is $t^2 \times f$ at 4 feet per second. We have made it for all velocities: $p = 2{\cdot}1\ t$; $f = 4\ t$."

Formula 8. "In this rule $p = 2{\cdot}1\ t$; $f = 2\ l$ as available for strength."

Formula 9. "The breadth of teeth suitable for wear is $f = 2\ \frac{H}{v}$; or, according to Rennie, $f = 1{\cdot}8\ \frac{H}{v}$; if we incorporate the latter element with formula 8, we get formula 9."

Formula 10. Buchanan's rule for the thickness of cast iron teeth for wheels, see his "Practical Essay on Mill Work." John Weale, London, 1841, p. 109. "Find the number of horses which are equivalent to the power of the first mover of the train of machinery, and divide that number by the velocity, in feet per second, of the pitch line of the pinion or wheel. Extract the square root of the quotient, and three-fourths of this root will be the least thickness of the tooth for the wheel or pinion, in inches."

Formula 11. From Fairbairn's "Mills and Mill Work," 1863, p. 45, deduced from Tredgold's rules. Insert ·821 for brass, ·891 for wood.

Formula 12.[9] From Fairbairn's "Mills and Mill Work," 1863, p. 46, deduced from Tredgold. Insert ·674 for brass, ·795 for wood.

Formula 13, Empirical rule by Box in his "Mill Gearing," p. 26, for ordinary wheels of cast iron in use. Insert ·05 in formula for wooden teeth. For bevel wheels p should represent the *mean* pitch, not that usually given, which is the maximum measured on the greatest circle of the working cone.

Formula 14. "Molesworth's Pocket Book of Engineering Formulæ. London, 1875, p. 200." $t = {\cdot}45\ p$; $l = {\cdot}75\ p$; height of tooth above pitch line, ·33 p; $f = 2\ p$ in small pitches and $3\ p$ in large.

Formula 15. "D. K. Clarke's Tables and Rules, 1877, p. 738." Insert 33·9 for gun metal (copper and tin); 20·2 for wrot. iron; 13·1 for steel.

Formula 16. Nystrom's rule, quoted by Haswell, 1867, p. 516.

Formulæ 17 and 18. Nystrom's rules, corrected from his 1854 edition of his Pocket Book.

Formulæ 19 and 20. Nystrom, 1875, p. 297. The face, f, is generally made $= 2{\cdot}5\ p$; $\therefore\ f = 5{\cdot}435\ t$; $t = {\cdot}46\ p$, and $p = 2{\cdot}1739t$.

Formula 21. Jones and Laughlins' "Useful Information for Engineers," p. 51. Height of the tooth $= {\cdot}32\ p$; depth of the tooth $= {\cdot}38\ p$; $t = {\cdot}48\ p$ for cast wheels; $t = {\cdot}5\ p$ when cut.

Formula 22. Haswell, 1860, p. 163. Rule "*To find the Horses' Power of a Tooth, the Dimensions and Velocity being given.*"

"Thickness $^2 \times 3000 =$ pressure" (a)

"$\dfrac{\text{Pressure} \times \text{velocity in feet per minute}}{33000} =$ H. P."

"Thickness $\times$ 2·1277+ = the Pitch."

"Thickness $\times$ 1·5384+ = the Length."

"The Breadth should be 2·5 times the Pitch."

"The Thickness should be ·47 of the Pitch."

The velocity here is given in feet per minute, whence inserting velocity in Fps and the elements of the pressure (a), we will have:

$$H = v\, t^2\, 5{\cdot}45$$

Formula 23. Haswell's (1867, p. 516) Rule for "the Depth of a Tooth, when the Horses' Power alone is given."

"Extract the square root of the quotient of the horses' power, divided by the velocity of the teeth in feet per second, and multiply it by ·465."

Formula 24. "Engineer and Machinist's Assistant," p. 96. With a pitch of 3 inches, $t = 1{\cdot}4$ inches; $l = 2{\cdot}1$ inches; least $f = 4{\cdot}2$ inches.

Notes on Table II.

Formula 1. Tredgold, giving results near those of his table in his treatise on the steam engine. John Weale, London, 1838.

Formulæ 2 and 6. "Engineer and Machinist's Assistant," Glasgow, 1856, p. 92. "Thus, for cast iron teeth this rule gives $p =$ ·0517 $\sqrt{S}$, and for a pressure of 15,000 lbs. we have $\sqrt{S} = \sqrt{15000}$ = 122·5 and ·0517 $\times$ 122·5 = 6·333 inches. The wheel from which this example is taken has been several years in action, and has an actual pitch of 6 inches, and the mean pressure at the pitch circle is 14,786 lbs.

Clearance of teeth $\frac{1}{15}$ of the pitch; for brass teeth use ·0723, for wood ·0785.

Formulæ 4 and 5. Rankine in his "Tables and Rules," p. 233, gives a rule "to find the *least thickness* suitable for the teeth of a wheel. Divide the pressure in lbs. to be transmitted by 1500, and extract the square root of the quotient for the thickness on the pitch circle in inches."

"To find the *least pitch*, multiply the least thickness on the pitch circle by 2·2."

"To find the *least breadth*, divide the pressure in lbs. to be transmitted by 160, and by the pitch in inches."

In his "Mechanical Text Book," Rankine adds: "The *thickness* of a tooth is fixed according to the principles of strength, and the *breadth* is so adjusted that when multiplied by the pitch the product shall contain *one square inch* for each 160 lbs. of force transmitted by the teeth."

Formula 7. Can be loaded to half more and yet be within the elastic limit. Insert ·035 for brass and ·038 for wood. S in this rule is $\frac{1}{10}$ the breaking weight.

Formula 9. W. C. Unwin, 1877. $\frac{1}{10}$ of the stress, by this rule, should be put on wooden teeth. This formula, deduced from table on page 184 of his "Elements of Machine Design," D. Appleton & Co., New York, 1877. For wheels of 3 inch pitch, when the load is quietly laid on, $S = 5625$; when shock is moderate, $S = 3600$, and when shock is excessive $S = 2493$ lbs. for safety.

Formula 11. Box on the absolute strength of the teeth of wheels for cranes and other like purposes. The stress being put on the teeth at very low velocities, and calculated at $\frac{1}{10}$ of the stress which would break the teeth. Box estimates shrouded teeth of same pitch and face at 40 to 50 per cent. stronger than those not shrouded, and wooden teeth of *Hornbeam*, which has a tensile strength of $\frac{3}{10}$ that of cast iron, at $\frac{1}{213}$ the transverse strength of iron teeth.

Formula 13. D. K. Clarke. Insert 1600 for gun metal, 2600 for wrought iron, 2900 for steel.

Formula 14. D. K. Clarke, 1877. Equal to $\frac{1}{10}$ the breaking stress. For cast iron 180 to 310, for gun metal (copper and tin) 310, for wrought iron 520, for steel 800.

D. K. Clarke's rules for the "ultimate transverse strength of the teeth of ordinary cast iron wheels" are based upon an assumed line of rupture, the diagonal of a square whose side is the length of the tooth, which is in fact the line of least theoretic resistance with the stress at the corner, although not the line of actual fracture, according to which for strength alone it is needless to make the face of wheels more than twice the length of the tooth. Quoting Fairbairn, Clarke gives to wooden teeth a thickness equal to $\frac{3}{8}$ of the pitch, whereof the iron teeth

have $\frac{3}{5}$, no allowance being made to gain clearance, for when properly shaped the teeth will all work closely into and out of their interspaces.

Formulæ 17, 18, 19, 20. Mr. Nystrom's earlier rules are evidently of English origin, and as good as they, having been derived from $S = 1600\ t^2$, but his later formulæ which with gear having strongly rooted teeth of good material, with well fitted and mounted wheels, shafts and bearings, are certainly in every way capable of transmitting the power assigned to them, and then he assures us he has deduced them from gears in actual use.

Formulæ 17 and 18. Nystrom, 1854. Abrasion included in these formulæ and $f = 2{\cdot}5\ p$.

Formula 19. Nystrom, 1875. This rule provides for carrying the load always on two teeth, and is thus equivalent to $\frac{1}{16}$ the breaking stress.

Formulæ 19, 20 and 21. Nystrom, 1877. "The coefficient I have given for strain on teeth is only $\frac{1}{8}$ of the breaking strain, although it is about three times the old rule. Thus:

$$\text{Safety strain} = S = \frac{150\,f\,t^2}{L} = \frac{150 \times 7{\cdot}5 \times 1{\cdot}9044}{{\cdot}175} = 12242{\cdot}57$$

If you count two teeth in gear at a time, the safety is $\frac{1}{16}$ of breaking strain."

Formula 22. Haswell. $f = 2{\cdot}5\ p$; $t = 2{\cdot}127\ p = 1{\cdot}5384\ l$.

Formula 23. Haswell's (1867, p. 515) Rule for "the Dimensions of a Tooth to Resist a given Stress."

"Multiply the extreme pressure at the pitch line of the wheel by the length of the tooth in the decimal of a foot; divide the product by the *Value* of the material of the tooth; the quotient will give the product of the breadth and square of the depth."

"The *Value* of cast iron for this or like purposes may be taken at from 45 to 65. In this case it is taken at 60."

Formula 24. James Christie, Philadelphia, 1877. This rule represents $\frac{1}{8}$ the breaking stress. See his discussion of the subject.

Having presented most of the rules on the strength of the teeth of wheels to be found in the existing engineering treatises published at home and abroad, it will help to an understanding of their essential elements by giving in detail some of the experiments made from time to time upon the material of which most wheels are made.

It is certainly necessary to know the strain that breaks a piece of projecting cast iron of given size and shape, when the stress is laid on quietly, as well as when it is driven on with considerable velocity. It is also important to know the fractional part of the rupturing weight or stress which may be repeatedly laid on with perfect safety, to insure the continuance of cohesion under the usual conditions of working.

Upon these essential features of each case the criteria of almost every engineer's guide book is silent. To stand safely, therefore, on the certainties of knowledge, one must have definite and accurate means of ascertaining the mechanical properties of the materials upon which dependence is to be placed, and in the line of this branch of the inquiry we present the data from which Boulton and Watt made their rule for the strength of the teeth of wheels.

"A bar of cast iron one inch square and twelve inches long bears 600 lbs. before it breaks; one inch long will bear 7200 lbs., and $\frac{1}{15}$ of this = 480 lbs., which is the load that should be put on a wheel."

Prior to this test we have the record of John Banks, in 1803, on 1″□ cast iron 3′ between supports giving, in 10 experiments, an average of 844 lbs., ranging from 730 to 972 lbs. at the middle of the bar, producing rupture.

To find the pressure that breaks 1″□ section at 1″ distance from the support we have $\frac{844 \times 36}{4} = 7596$ lbs.

Rondelet's six trials in Paris in 1814 averaged 6012 lbs., and later, Tredgold's five trials averaged 7416 lbs. on cast iron bars of same section and length.

In Pole's work on "Iron," 1872, page 90, occurs the following: "There is an exceedingly simple rough datum for the transverse strength of cast iron which is well worth committing to memory. It is, *that a bar* 1 *inch square and* 1 *foot long will break with a load of about* 1 *ton* hung on the middle."

In this we have $\frac{2240 \times 12}{4} = 6720$ lbs. on 1″□ by 1″ long.

Barlow says: "Cast iron has its elasticity destroyed with about one-third the weight that will produce rupture; it ought not therefore to be loaded in permanent constructions to more than this amount."

Mr. F. Campin, C. E., in the *Artizan*, says: "It is found that a cantilever of cast iron 1″ long, 1″ wide and 1″ thick breaks under an

extreme load of 8000 lbs. To find the breaking weight of any given cast iron cantilever loaded at the end, multiply the breadth in inches by the square of the thickness in inches, the product by 8000, and divide by the length in inches. In practice, it is usual to make the working stress $\frac{1}{3}$ of the breaking weight, then the formula for safe load would be: $S = \frac{8000 f t^2}{6 l}$; or, to put it in the same form as the others, see formula 10 in table II.

We can therefore rely upon Boulton and Watt's data, *i. e.*, 7200 lbs. breaks a bar of cast iron 1″□ by 1″ long; $\frac{7200}{3} = 2400$ lbs., the elastic limit, which, if exceeded, would end in rupture, and $\frac{2400}{5} = 480$ = the safe load.

The question of how many pounds pressure upon the point of the tooth, whose elements are given above, will be necessary to break it, may now be considered.

$$\text{For this we have } \frac{7200 \times 7{\cdot}5 \times 1{\cdot}38^2}{2{\cdot}1} = 48970$$

and $\frac{1}{15}$ of this is 3265 lbs., which is near the average of the rules tabulated in this article.

Mr. J. Anderson, "On the Strength of Materials and Structures," D. Appleton & Co., New York, 1872, says: "A cast iron bar of good quality, 1 inch long and 1 inch square, loaded at the end, would break with about 6000 lbs."

"The tooth of a cog wheel is to be considered as in similar conditions to such a bar, that is, in the condition of a beam fixed at one end and loaded at the other, and its resistance to fracture is proportional to its length or projection inversely, to its breadth or face directly, and to the square of its depth or thickness.

Tests of American cast iron are given herewith for comparison, reference being had to "Reports of Experiments on the Strength and other properties of Metals for Cannon," published by officers of the Ordnance Department, U. S .A., 1856. We find as the result of 18 tests of transverse strains, made by Maj. Wm. Wade upon various samples of American irons, the following results after the second and third fusions, that is, once and twice melted in the foundry furnace:

Maximum unit of strength,	.	.	11,046 lbs.
Minimum "	"	.	6,207 "
Average "	"	(18 tests)	7,969 "

These trials were made with bars each 24″ long (and averaging 2 ins. square), supported at both ends, 20″ between supports. "The 'Unit of Strength' represents the weight, in pounds, required to break a bar one inch square, supported at one end, the weight being applied at a distance of one inch from the point of support. For square bars it is determined by the formula $\frac{lw}{4bd^2} = S =$ the unit of strength; l being the length between the supports, w the breaking weight, b the breadth of the bar and d the depth.

From John Farey's Treatise on the steam engine, London, 1827, p. 628, we extract the following particulars of Mr. Loyd's "strong cranes." "The largest size is adapted to lift twenty tons weight; the chain is made of iron, 1¼″ diameter, and winds round a grooved barrel 22″ diameter. The axis of this barrel is made of wrought iron 4″ square; the gudgeon at one end is 3″ diameter, and 3½″ long; the neck at the other end is 4¾″ diameter, 3½″ long. The barrel is turned round by this neck to wind up the chain; and the cast iron cog-wheel, which is fixed on the extreme end of the axis, beyond the neck to turn it round, is 6′ diameter with 152 teeth, which are 1·49″ pitch, and 3¼″ broad.

"The teeth are rounded at the ends nearly to a semicircle, and the spaces between the teeth are also hollowed out nearly to a semicircle; this form gives the teeth very great strength at the roots, where they join to the rim of the wheel. The wheel is turned by a cast iron pinion of 17 teeth, which are of a corresponding form to those of the wheel, but the pinion has a circular rim, or flange, at each end of the teeth, which greatly strengthens them, being cast in one piece with the teeth. With this form of teeth, only one pair of the teeth of the wheel and pinion are in actual contact at the same time, so that one tooth bears all the strain."

Calculation for the teeth:

$$\frac{44800 \times 22}{72} = 13689 = \text{pressure upon the teeth.}$$

Then $\frac{13689}{1{\cdot}49^2 \times 3{\cdot}25} = 1898$ lbs. is the propor-

tionate pressure for cast iron teeth of 1″ pitch and 1″ face. This is 17¼ times our assumed standard of 110 lbs."

"These cranes are always proved by lifting the full weight that they are intended to bear. * * * They rarely break wheels, but sometimes twist, yet never break the necks of the drum shafts."

A curious application of a rule for the teeth of mill wheels occurs in "Farey's" Treatise, p. 627, which is quoted in full.

"The great wheel of a very excellent pocket watch, made by Mr. Pennington, is ·764 of an inch diameter, with 60 teeth, which are ·04 of an inch pitch and ·04 of an inch broad. The strength of these teeth is therefore $·04^2 \times ·04 = ·0064$. To find the force which these teeth transmit, a wheel was affixed to the watch key, and a sufficient weight applied by a silk thread to the circumference of the wheel to wind up the watch.

"It appeared that the constant pressure upon the teeth is ·83 of a pound, which ÷ ·0064 strength of the teeth, gives 130 lbs. for the proportionate strength of teeth, one inch pitch and one inch broad, instead of 110.

"This watch has been in use for ten years past. The wheel is made of fine yellow brass, hammered very hard; it is gilt, but the gilding is not yet worn off the teeth."

The 110 lbs. referred to in quotation from Farey represent *a unit of measurement;* it is the pressure that may constantly be applied to the teeth with perfect safety, being from $\frac{1}{10}$ to $\frac{1}{15}$ of the breaking strength of a wheel one foot pitch diameter and teeth of one inch pitch and one inch face.

A correspondent of the *Engineer* says: "I herewith send you a rule for the strength of the teeth of wheels. As an example, 3″ pitch is usually taken by all who have written on the subject, and at a velocity of 3 Fps.:

Tredgold gives it	15·	H. P.
Eng. and Mach. Assistant gives it	14·5	"
Hick "	10·	"
Roberton "	10·	"
Carmichael "	9·91	"
Farey "	13·5	"
Buchanan "	9·4	"

"These are all nearly correct, taking their data from wheels actually in use, and going at or near about three feet per second.

"I find for general use Tredgold's data and 'The Engineer's Assistant' the best, with the correction proper for the velocity.

"The breadth to be twice the pitch in all calculations for strength; any extra breadth is of no further use except for extending the bearing surface and lessening the wear. Practically, three times the pitch is the utmost limit. Fine pitch broad wheels are very apt to strip gear, especially when put on slight shafting which is the most deficient in lateral stiffness; sometimes whole teeth, and at others, portions, will break off diagonally with the radial line of tooth.

"Buchanan gives the best information on the teeth of wheels of any writer I have yet met with."

We add an original treatment of this subject by Mr. J. Christie, Engineer, Pencoyd Iron Works, Philadelphia:

"In most cases of gearing the question of least pitch is an important one, not only because it contributes to smoothness of running, but also because the linear tooth bearing increases with the lessening of the pitch.

"Many of the old English rules for strength of teeth are based upon the presumption that the teeth do not in action bear over the entire length of face, but only on the corners, in which case the line of rupture is a diagonal, rendering any increase of face of tooth beyond double the length of the tooth needless. This rule may be very well for gearing on weak or long shafts, or, worse still, when they overhang the bearing on weak shafts.

"To secure the advantages of face, the parts should be proportioned so as to preserve an even and continuous bearing of the teeth at all times.

"I have collected a number of cases, varying from 1″ up to 4″ pitch where the teeth are strained up to their utmost safe endurance, and feel convinced that the teeth of wheels can be treated in a rational way, as a beam rigidly supported at one end and loaded at the other; that is, loaded at the pitch line and all the load on one tooth. Further assuming that the length of beam or tooth is taken at $\frac{4}{10}$ of the pitch, a usual proportion of distance from root of tooth to pitch line, and also taking the *modulus of rupture* at 36,000, would give for the teeth of cast iron wheels a breaking strain of 3,700 lbs. for each inch of pitch and face, and advancing directly as the pitch and the face, although the transverse strength of rectangular sections increases as the square of the depth, yet in the case of the teeth of wheels there is

an inverse *decrement*, owing to the proportional increase of length of tooth.

"My rule would therefore be for cast iron teeth. *Pitch* × *face* × 3700 = the ultimate breaking load in lbs. On account of the imperfect elasticity of cast iron, the working load should never exceed ⅓ of the breaking strain and then under the most favorable conditions, such as well-fitted gear, rigidly supported, running at moderate speed and stress evenly distributed. For strains suddenly applied, the factor of safety should be 6, and when accompanied by severe shocks and sudden reversion of strains it should be 8. These are my conclusions, and I am prepared to sustain them by numerous examples, a few of which are given herewith; Spurwheels of $1\frac{1}{16}''$ pitch and 4″ face on a crane, which for years have been subject to a tooth strain of 500 lbs. per inch of face; one of 4″ pitch and 12″ face, every day working under a strain of 25,000 lbs. and often 30,000 suddenly applied on the teeth; another of $2\frac{1}{4}''$ pitch and 8″ face, subject to a frequent stress of 10,000 lbs., but which has had two breakages when the strain amounted to 13,500 lbs., suddenly applied, or 1700 lbs. (nearly) per inch of face.

"In estimating the moment of resistance of the tooth, I use the *modulus* suggested by Rankine, viz., 18 times the weight applied at the center necessary to break a bar 1″ square and 1″ between supports. In ordinary foundry iron this may be accepted as averaging 36,000 lbs. as stated, but as there is a wide range in the strength of cast iron or another material may be applied, a simple experiment will determine the proper *modulus*, and according as the result obtained will exceed or fall below 36,000, so will the proper coefficient in the formula vary from 3700."

A Treatise on the Strength of Cast Iron Beams, by Wm. Turnbull, London, 1831, says: "Now it has been found, by very accurate experiments, that a bar of soft gray cast iron, 1 inch square and 34 inches between the supports, will bear a load of 300 lbs. in the middle of its length, while the elastic force remains perfect (see Tredgold on Cast Iron, Art. 45.)." Therefore, by substituting these numbers in the usual equation, and employing also the usual notation, we have:

$$l\,S = 850\,b\,d^2$$

And when the beam is fixed at one end and loaded at the other we have:

$$l\,S = 212{\cdot}5\,b\,d^2$$

Putting l in inches, and dividing this by l we have:

$$S = \frac{2550\ b\ d^2}{l}$$

If we now employ the notation and sizes of tooth given in statement above, in this last formula, and work it out in the same manner as those in the tables, we will have:

$$S = \frac{2550\ f\ t^2}{l} = 16130 = \text{the safe stress within}$$

the limits of elasticity which may be repeatedly put on this tooth.

From Practical Rules for the Proportions of Cog Wheels and Shafting, by E. R. Walker, of Haigh Foundry, Wigan, Newcastle-under-Lyme, 1868, we select the following observations and rules, changing the notation:

"The results will be found to give a good average margin of strength with ordinary materials. The rules are based upon and have been tested by a large number of examples in actual operation, and they have been used in a considerable practice for some years."

"*To find the extreme strain which the teeth of any wheel are capable of transmitting.*

"Calling X = breaking load of tooth in lbs.
S = working " "
H = indicated horse-power.
R = radius of power.
p = pitch of teeth in inches.
f = face " "
d = diameter of wheel in inches.
n = Rpm.
v = speed of wheel rim in Fps.
m = 3 for very slow speed without shock.
= 4 when rim of wheel runs 3 Fps.
= 5 " " " 5 "
= 6 " " " 10 "
= 8 " " " 15 "
= 10 " " " 20 "
= 12 " " " 30 "
= 14 " " " 40 "

We have $X = 2000\ p\ f$ 1

"*The extreme or breaking load being found, and the speed given, to find the working load the wheel should bear*

$$S = \frac{X}{m} \qquad 2$$

"*The working load and the speed being given, to find the extreme or breaking load*

$$X = S\,\mathrm{m} \qquad 3$$

"*Find m according to speed of gear and substitute in formula.*

"*To find the size of teeth to carry a given load in lbs.*

$$\frac{X}{2000} = p\,f \qquad 4$$

"For bevel wheels take the mean pitch.

"Wheels of ordinary breadth are increased in strength if shrouded to the points of the cogs in the proportion of 5 to 3, and if shrouded to the pitch line in the proportion of 3 to 2.

"Wooden teeth, when the rims of the wheels run over 30 Fps., will drive as great a weight as cast iron of the same dimensions.

"*To find the strain on the teeth of wheels on the shafts of engines, etc.*

Rule for single engines or pairs of engines where the cranks are opposite to each other.

$$\mathrm{S} = \frac{H\ 864}{v} \qquad 5$$

Rule for pairs of engines where the cranks are fixed at right angles:

$$S = \frac{H\ 576}{v} \qquad 6$$

Rule for water wheels or engines with uniform motion, or general machinery:

$$S = \frac{H\ 550}{v} \qquad 7$$

Having found the working load or strain on cogs, proceed as before."

The amount of power that may be transmitted by gears after the pitch and face have been determined depends upon the speed of the load laid upon their teeth, which, apart from their size and shape, opens up new conditions of the problem, in which the effects of impact, vibration and centrifugal force due to high velocities must be considered as modifying somewhat both the pitch and the face.

Provision for these conditions can easily be made after the absolute strength of the teeth is determined and the elastic limit definitely known.

In practice, the efficiency of a wheel, even with ample pitch and face, will much depend upon the accuracy with which the parts hold their integrity of adjustment while working; for if the stress be laid on at the corners of the teeth, then the great advantage to be derived from a broad wheel is necessarily lost and might as well have not been provided.

It must be admitted that the shape of the tooth has something to do with its strength, and yet no allowance appears to have been made by the rules tabulated above for such distribution of the metal, the breaking strength being based upon the pitch or thickness of the teeth at the pitch line or circle, as if the thickness at the root of the tooth were the same in all cases as it is at the pitch line.

There are good reasons for taking account of this; according to one rule for shaping teeth the flanks should lie within radial planes, which of course would reduce the section of metal and weaken the teeth accordingly; to another rule the flanks should lie within parallel planes, which would comply fairly with the terms of those rules based on the tests of semi-beams of uniform square section throughout their length; to another rule, like Adcock's, for example, which makes the tooth decidedly pyramidal in form, with broad base, thereby greatly augmenting the strength of the tooth, in one case measuring 2 inches in a pitch of $2\frac{1}{2}$ inches, the comparative strength being for the parallel tooth $(2{\cdot}5 \times {\cdot}46)^2$, and for the pyramidal tooth 2^2, or as 1·3225 : 4. All other rules provide for a spreading of the base of the tooth more or less between these extremes.

Even in well-shaped cut gears the root of each tooth has about $\frac{1}{8}$ additional metal more than the section at the pitch line, which would augment the strength of each tooth in the proportion of 1·2656 to 1.

So that while the rule based on the cog as a semi-beam may not be absolutely exact, the methods of calculation which do not include the root section of a tooth are very false.

"We know already that each material gives its own figures," quoting Weyrauch's words, and so also do the form of the tooth, the face as affected by the maintenance of adjustment to line and the uniformity of the velocity with which the load is transmitted through the teeth.

"The question is not about theoretical crotchets; and the names of the experienced practical men who have made these investigations should be sufficient warrant to those who are without experience. Yet if a new process is to be generally accepted, it must be theoretically sound, simple in application, and not contradictory to past experience."

THE AMERICAN RIVER PADDLE-WHEEL STEAMBOAT "MARY POWELL."

By Chief Engineer Isherwood, U. S. Navy.

The *Mary Powell* is a typical example of the American paddle-wheel steamboat employed on the rivers of the Eastern portion of the United States. The hull is of wood, coppered, and is exceedingly light and shallow, depending for strength on an immense timber truss, or "hog-frame," erected on each side, and on a very deep keelson supporting, along the centre of the vessel, poles rising many feet above the roof of the saloon, from the tops of which sloping iron rods suspend the guards and ends of the hull. Of course, such a structure is suitable for smooth water only, and the elegant saloons erected upon it, of light joiner-work, afford spacious and convenient accommodations for the crowds of passengers carried.

The *Mary Powell* plies between New York City and Rondout, on the Hudson River, a distance of about 88 statute miles, making the round trip once a day during the summer "season" of each year, extending from about the middle of May to the middle of October. She carries passengers only, and her trips are made with great regularity, the times of starting and stopping varying but a few minutes from her schedule time. Her draught of water varies very slightly also, and her speed throughout the entire run may be taken, without sensible error, as absolutely uniform. The air resistance of the hull, must, at its high velocity, be considerable, as the top of the saloon is about 30 feet above the water, while the immersion of the hull, exclusive of the keel, is only 6 feet.

There is but one engine—placed in the centre of the vessel and bolted to its keelsons—and it is as typical as the hull, being a first-class specimen of the overhead-beam, or "walking-beam," kind, used exclusively on such steamboats, the beam being supported upon a lofty triangular gallows-frame of wood, very stiff and very light. The boilers, also, are peculiar to this style of steamboat. They are two in number, and placed outside of the hull upon the projecting guards behind the wheel-houses. This is the only place available for them, and as no more boiler space can be obtained than there is room for on

these guards, their rate of combustion has to be forced enormously by powerful fan-blowers to furnish sufficient steam for the large power required. Independently, too, of the limited space that can be devoted to the boilers, no greater weight of them can be allowed, even if more space was available. Anthracite of small nut size is burned, giving about one-sixth refuse. The vessel is coaled at Rondout, and carries just enough for one round trip. The paddle-wheels are of the usual radial kind. For river steamers carrying large numbers of passengers, no system, as a whole, has ever been devised equal to the paddle-wheel steamboats of the *Mary Powell* type.

The entire machinery with its appurtenances, including the water in the boilers, weighs about 210 tons; the coal embarked weighs about 30 tons; total in the engineer department, 240 tons, or 27·24 per centum of the vessel's displacement.

As there is no account to be found of the performance of such a vessel, my friend, the accomplished engineer, Mr. Theron Skeel, having occasion to make many trips in the *Mary Powell* during the summer of 1877, kept for me an accurate record of her running time between the cities of New York and Newburgh, 59 statute miles apart, together with the boiler pressure, vacuum, temperature of the feed-water, revolutions of the motive and blowing engines by counter, consumption of coal, etc., the coal being the amount purchased by the owner of the boat. He also took on each trip a large number of indicator diagrams from both ends of the cylinder, and made the other observations to be found in this article. The means from all these diagrams are given in the table of "performance."

During the round trip no water was blown from the boilers, and they remained entirely free of scale. There was no means of ascertaining the temperature of the gases of combustion in the chimney, but a piece of zinc suspended therein at the level of the top of the steam-drum melted promptly, showing the temperature to be above 750 degrees Fahrenheit. The temperature of the steam in the boiler, considered as saturated steam, would be 272 degrees Fahrenheit or more than 478 degress Fahrenheit less than that of the gases of combustion passing through the steam-drum, which difference, taken in connection with the large extent of surface in the drum and upper part of the uptake, must have caused a considerable steam superheating. There was no means, however, of ascertaining this fact quantitatively, but it is believed that the superheating was sufficient to prevent any

steam condensation in the cylinder other than that due to the development of the total horses-power.

In the table of "performance" hereinafter given will be found grouped all the quantities observed and calculated. The power developed is that of the motive engine alone, exclusive of the power exerted by the blowing engines in driving the fans. Of the latter power no approximation can be made, as these engines used the steam greatly throttled but exhausted into the condenser. The weight of steam used, calculated from the indicator diagrams, is also exclusive of the weight consumed by the blowing engines; hence, if it be assumed that there was no condensation in the cylinder of the motive engine other than that due to the development of the total horses-power, then the cost of the horses-power in weight of steam consumed per hour can be ascertained. As the motive engine developed 1744·884 total horses-power, and as the indicator accounted for 38258·264 pounds of steam consumed per hour in its cylinder, there follows that the total horse-power was obtained for 21·93 pounds of steam consumed per hour.

The economic vaporization by the boilers can be ascertained, without error of practical importance, by assuming the weight of steam consumed by the blowing engine to be five per centum of the weight consumed by the motive engine. Adding this weight to the 38258·264 pounds of steam consumed by the motive engine per hour, there results 40171·177 pounds of steam evaporated per hour, from water at the temperature of 120 degrees Fahrenheit, and under the boiler pressure, by 6050 pounds of anthracite, or 6·64 pounds of water vaporized per pound of coal. This, of course, supposes no condensation in the motive cylinder, which was probably the fact, an inference warranted by the superheating of the steam, by the above cost of the total horse-power in pounds of steam consumed per hour and by the boilers' economic vaporization of 6·64 pounds of water per pound of coal consumed at the great rate of 39·286 pounds per square foot of grate surface per hour.

In computing the quantity of heat transformed into the total horse-power developed by the expanded steam, the mechanical equivalent of the heat required to raise the temperature of one pound of water from 32 to 33 degrees Fahrenheit is taken at 789¼ pounds, instead of Joule's equivalent of 772 pounds. The latter has long been known to be too small, and the former is the result of the experimental researches of Tresca and Laboulaye, endorsed by Regnault, Piobert, Combes, Bertrand and Morin. It should be universally adopted.

Hull.

Length on the load water-line from the forward edge of the rabbet of the stem to the after edge of the stern-post,	290 ft.
Extreme breadth on the load water-line,	34 ft.
Depth of hold from top of floor-timbers to under side of deck-plank,	9½ ft.
Depth from load water-line to lower edge of rabbet of keel,	6 ft.
Depth of keel below the lower edge of its rabbet,	6 in.
Area of the greatest immersed transverse section to load water-line,	198·5 sq. ft.
Displacement to load water-line	881· tons.
Ratio of the length to the breadth,	8·529
Ratio of the greatest immersed transverse section to its circumscribing parallelogram,	0·973
Ratio of the displacement to its circumscribing parallelopipedon,	0·520

Engine.

There is one overhead beam-engine with a wooden gallows-frame. The cylinder is vertical and has four balanced poppet-valves, two for admitting and two for exhausting the steam. The steam-valves function also as expansion valves by means of the mechanism known as Stevens' cut-off. The condensation of the steam is effected in a jet-condenser. The air-pump is vertical and single-acting. The cylinder is not steam-jacketed; its ends, its valve-chests and its side-pipes have no protecting covering, but its cylindrical portion and all the steam-piping connecting it with the boilers were well covered with asbestos felting.

During the performance hereinafter given, the steam-valves closed when 0·486 of the stroke of the piston was completed. There was but little exhaust lead, and the exhaust-valves closed and cushioned the steam when the piston was at 0·232 of its stroke from the end.

Number of cylinders,	1
Diameter of cylinder,	72 in.
Diameter of the piston-rod,	6¾ in.
Net area of the piston, exclusive of the piston-rod,	4053·62 sq. in.
Stroke of the piston,	12 ft.
Space displacement of the piston per stroke,	337·802 cub. ft.

Clearance of the piston,	1⅛ in.
Capacity of steam-passage or nozzle at one end of cylinder,	8·488 cub. ft.
Aggregate space in clearance and steam-passage at one end of the cylinder,	12·300 cub. ft.
Least diameter of the seat of the upper disc of the steam-valve,	15⅜ in.
Least diameter of the seat of the lower disc of the steam-valve,	14¾ in.
Least diameter of the seat of the upper disc of the exhaust-valve,	14¾ in.
Least diameter of the seat of the lower disc of the exhaust-valve,	15⅜ in.
Area of steam-port, exclusive of valve-stems,	352 sq. in.
Diameter of air-pump (single-acting),	40 in.
Stroke of air-pump piston,	62 in.

Blowing-Engines.

There are two blowing-engines—one for each boiler—employed in driving fan-blowers to produce an artificial draught. Each blowing-engine consists of one cylinder 12 inches in diameter, with 12 inches stroke of piston, geared by a belt to a Dimpfel blower 5 feet in diameter and 32 inches wide, which makes five revolutions to each double stroke of the steam-piston. The steam is cut off by lap on the steam-valve at three-fourths of the stroke of the piston from the commencement.

The delivering-nozzle of each fan-blower is connected by a rectangular conduit of sheet-iron with the closed front of the two ash-pits of its boiler, and they receive the air-blast beneath the grate-bars.

Boilers.

There are two boilers, one placed on each guard of the vessel immediately behind the wheel-house. They have lower flues in direct continuation of the furnaces, with tubes returned above the flues and furnaces. The two boilers have no connection of any kind; they have separate chimneys, are fed separately with both water and air-blast and deliver their steam through separate pipes into one large steam-pipe. The external surfaces of the boilers are well covered with asbestos felting. The following is a description of each boiler:

The front portion of the shell is rectangular in plan, with flat sides

and a semi-cylindrical top. The back portion is cylindrical, with its top a horizontal continuation of the top of the semi-cylinder of the front portion. The front portion is 10 feet 9 inches high, exclusive of water-pan beneath the grates, 8 feet 11½ inches long and 11 feet wide. The back portion is 10 feet in diameter and 16 feet 1 inch long, with its bottom 9 inches above the bottom of the front portion.

The furnaces are two in number, each 4 feet 9¾ inches wide by 8 feet long. The crown is an arc of 7 feet 3 inches radius, joined to the vertical sides by quadrantal curves of 8 inches radius. The flat water-space between the furnaces is 6½ inches wide, and between the furnaces and shell 5 inches wide, including thicknesses of metal.

The opening for the furnace door is semi-circular on top, 22 inches wide and 22 inches high. The height from the top of the grate-bars to the top of the furnace is 3 feet. The bridge-wall is 7 inches wide, including thicknesses of metal.

Immediately behind the bridge-wall is a combustion-chamber, separate for each furnace. Its extreme height is 3 feet 2 inches and its length is 3 feet. In cross-section its outline follows the side and top of the furnace, the curve of the lower flue and of the cylindrical part of the shell, from which it is separated by a water-space 3½ inches wide, including thicknesses of metal.

From the combustion-chamber to the back smoke-connection there proceed, for each furnace, three lower horizontal cylindrical flues of 16 inches inner diameter, one lower horizontal flue of 14 inches inner diameter and one of 9 inches inner diameter. All these flues are 9 feet 1 inch in extreme length. The least water-space between them is 4½ inches, including thicknesses of metal.

The back smoke-connection is in common for both furnaces. It is flat on the top, and on the sides and bottom is concentric with the cylindrical part of the shell, from which it is separated by a water-space 3½ inches wide, including thicknesses of metal. The extreme height is 6 feet 4 inches, extreme breadth 9 feet 5 inches, extreme length 3 feet 7½ inches, all in the clear. The flat water-space between the end of the connection and the shell is 4½ inches wide, including thicknesses of metal. Access is had to the connection through a manhole of 18 inches diameter in the back end of the boiler.

From the back smoke-connection to the uptake there are returned over the lower flues and the furnaces 80 horizontal fire-tubes of 4½ inches outside diameter and 4·30 inches inside diameter; length, 16

feet 6 inches. The tubes are distributed in 5 rows vertically and 16 rows horizontally. The least distance from centre to centre of tubes, both vertically and horizontally, is 6·357 inches. The space in the clear, between the bottom of the lower row of tubes and the furnace-crown, is 7 inches. The height from the top of the upper row of tubes to the bottom of the lower row is 2 feet 4 inches. The heating surface of the tubes is calculated for their inside circumference, which is also the case for the flues.

The uptake is in common for all the tubes. The lower portion is rectangular, 8 feet 8 inches in extreme breadth, 55 inches in extreme width to the front of the shell and 31 inches in height. It is fitted with the usual uptake doors, giving access to the tubes for sweeping. The upper portion is irregularly-shaped, drawing in to a circle of 50 inches diameter at the top of the shell.

From the top of the uptake rises the chimney, 50 inches in inner diameter. The lower portion of the chimney, for a height of 12 feet above the top of the shell, is surrounded concentrically by a steam-drum of 90 inches diameter, with a flat top. The portion of the chimney so surrounded, together with the upper portion of the uptake, is steam superheating surface.

All the flat surfaces of the boiler are braced every 7 inches.

The following are the principal dimensions and proportions:

Number of boilers,	2
Extreme length of boiler, exclusive of projecting steam-drum,	25 ft. ½ in.
Extreme height of boilers, exclusive of steam-drum,	10 ft. 9 in.
Extreme breadth of boiler,	11 ft.
Height of steam-drum above the boiler-shell,	12 ft.
Projection of steam-drum forward of the boiler-shell,	1 ft. 3½ in.
Total number of furnaces,	4
Width of furnace,	4 ft. 9¾ in.
Length of furnace,	8 ft.
Aggregate area of grate surface,	154 sq. ft.
Number of lower flues,	20
Length of lower flues,	9 ft. 1 in.
Inner diameter of lower flues,	4 of 9 in., 4 of 14 in. and 12 of 16 in.
Number of tubes (iron),	160
Length of tubes,	16 ft. 6 in.

Outside diameter of tubes,	4½ in.
Inside diameter of tubes,	4·30 in.
Least space between tubes, in the clear,	1·857 in.
Aggregate area of heating surface in the furnaces,	416·00 sq. ft.
Aggregate area of heating surface in the combustion chambers,	262·00 sq. ft.
Aggregate area of heating surface in the lower flues,	338·00 sq. ft.
Aggregate area of heating surface in the back smoke-connections,	62·70 sq. ft.
Aggregate area of heating surface in the tubes,	2971·94 sq. ft.
Aggregate area of heating surface in the uptakes, to 9 inches above tubes,	675·36 sq. ft.
Total water-heating surface,	4726·00 sq. ft.
Aggregate area of steam superheating surface,	418·00 sq. ft.
Distance traversed by the gases of combustion from the centre of the furnace to their delivery into the uptake,	40 ft.
Diameter of chimneys (two in number),	4 ft. 2 in.
Height of chimneys above level of grates,	52 ft.
Aggregate cross-area over bridge-walls, for draught,	22·500 sq. ft.
Aggregate cross-area through lower tubes, for draught,	22·798 sq. ft.
Aggregate cross-area through the tubes, for draught,	16·136 sq. ft.
Aggregate cross-area of the chimneys	27·272 sq. ft.

PROPORTIONS.

Square feet of water-heating surface per square foot of grate surface,	30·558
Square feet of steam superheating surface per square foot of grate surface,	2·714
Square feet of grate surface per square foot of area over bridge-walls,	6·844
Square feet of grate surface per square foot of area through lower flues,	6·755
Square feet of grate surface per square foot of area through tubes,	9·544
Square feet of grate surface per square foot of area through chimneys,	5·647

PADDLE-WHEELS.

The paddle-wheels are of the ordinary radial kind

Diameter from outside to outside of paddles,	31 ft.

Number of paddles in each wheel,	26
Length of each paddle,	10½ ft.
Breadth of each paddle,	1¾ ft.
Deepest immersion of outer edge of paddles,	3½ ft.

Performance.

The following is the average performance of the *Mary Powell* between the cities of New York and Newburgh, on the Hudson River, during the summer of 1877. The running was very regular, the deviations at any time from the mean being very slight.

Vessel	Vessel's mean draught of water, in feet,	6½
	Vessel's greatest immersed transverse section, in square feet,	198·5
	Vessel's displacement, in tons,	881
	Deepest immersion of the outer edge of the paddles, in feet,	3·50
	Diameter of the paddle-wheel between centres of pressure of the paddles, in feet,	29·50
Engine.	Steam pressure in boilers, in pounds per square inch above the atmosphere,	28·5
	Proportion of the throttle-valve open,	0·75
	Fraction of the stroke of piston completed when the steam was cut off,	0·486
	Fraction of the stroke of the piston to be completed when the steam was cushioned,	0·232
	Number of times the steam was expanded,	1·984
	Vapor pressure in the condenser, in pounds per square inch above zero,	2·4
	Number of double strokes made by the piston per minute,	21·8
	Temperature of the injection-water in degrees Fahrenheit,	68
	Temperature of the feed-water (hot-well) in degrees Fahrenheit,	120
	Number of double strokes made per minute by the pistons of the blowing-engines,	75
	Number of revolutions made per minute by the fan-blowers,	375
	Air pressure in the fan-blower conduit, in inches of water, above the atmosphere,	1¼
Steam pressure in cylinder per indicator.	Steam pressure in cylinder, in pounds per square inch above zero, at beginning of stroke of piston,	41·42
	Steam pressure in cylinder, in pounds per square inch above zero, at point of cutting off the steam,	31·34
	Steam pressure in cylinder, in pounds per square inch above zero, at end of stroke of piston,	16·42
	Mean back pressure against the piston, exclusive of the cushioning, in pounds per square inch above zero,	3·55
	Mean back pressure against the piston, inclusive of the cushioning, in pounds per square inch above zero,	5·31
	Mean indicated pressure on the piston in pounds per square inch,	24·42
	Mean net pressure on the piston in pounds per square inch,	22·92
	Mean total pressure on the piston, exclusive of the cushioning, in pounds per square inch,	27·15

HORSES-POWER.	Indicated horses-power developed by the engines,	1569.432
	Net horses-power developed by the engines,	1473·029
	Total horses-power developed by the engines, exclusive of the cushioning,	1744·884
	Horses-power expended on the cushioning alone, above zero,	165·812
	Horses-power expended on the cushioning alone above the back-pressure of 3·55 pounds per square inch against the piston,	113·112
RATE OF COMBUSTION	Pounds of anthracite consumed per hour,	6050·000
	Pounds of anthracite consumed per hour per square foot of grate surface,	39·286
	Pounds of anthracite consumed per hour per square foot of water-heating surface,	1·280
Economic Results.	Pounds of anthracite consumed per hour per indicated horse-power,	3·855
	Pounds of anthracite consumed per hour per net horse-power,	4·107
	Pounds of anthracite consumed per hour per total horse-power,	3·467
SPEED.	Speed of the vessel per hour in statute miles of 5280 feet,	19·200
	Speed of the vessel per hour in geographical miles of 6086 feet,	16·657
	Slip of the centre of pressure of the paddle in per centum of its speed,	16·37
WEIGHT OF STEAM CONSUMED.	Fahrenheit units of heat transformed per hour into the total horses-power developed by the expanded steam, calculated for the mechanical equivalent of one Fahrenheit unit, 789¼ pounds raised one foot high per minute,	1823195·554
	Pounds of steam of the boiler pressure required to be evaporated from water at the temperature of 120 degrees Fahrenheit, to contain the above number of Fahrenheit units of heat,	1895·741
	Pounds of steam supplied per hour by the boiler to the cylinder, calculated from the pressure at the end of the stroke of the piston and from the back pressure cushioned,	36362·523
	Sum of the two immediately preceding quantities, or weight of steam in pounds consumed per hour, according to the indicator,	38258·264
	Pounds of steam cushioned per hour,	2365·428

German Scientific Credulity.—The well-known German professors, Fechner, Weber and Scherbner, have added their testimony to that of Zollner, in favor of the "spiritualistic" mediumship of Slade. In remarking upon Zollner's curious method of accounting for the phenomena by supposing an unknown fourth dimension of space, Tissandier thinks it strange that men who occupy some of the most importan chairs of the German University should be so easily deceived.—*La Nature.* C.

HARMONIC AND "BASIC" LINES AND TENDENCIES.

By PLINY EARLE CHASE, LL.D.,
Professor of Philosophy in Haverford College.

From the third law of motion it follows, as a necessary consequence, that cosmical and molecular bodies act and react in accordance with laws of perfect fluidity and of perfect elasticity. Hence, by introducing formulas of hydrodynamic and of undulatory motion, results can often be speedily reached which would, otherwise, require the use of long and difficult analytical processes.

Challis, in the *Philosophical Magazine*, has discussed a great variety of gravitating, electrical and thermal phenomena, from hydrodynamic considerations. Norton, in the *American Journal of Science*, has applied the principles of pneumatics to similar interpretations. The whole theory of thermodynamics rests mainly upon simple laws of motion, which may be readily deduced, as corollaries, from the fundamental propositions of "Newton's Principia."

In the *Monatsbericht* of the Berlin Academy for September and October, 1878, M. Paalzow describes a method of determining the fundamental lines of the oxygen spectrum with great precision, and publishes the wave-lengths of the five most persistent lines, which he regards as specially characteristic. His measurements are given in millionths of a millimetre, in the following table, together with three other series, which serve, by comparison, to indicate the influence of two co-ordinate laws:

	Paalzow.	Harmonic.	Reciprocal.	Geometrical.
Oα	602	602	601·91	599
Oβ	558·2	558·24	558·27	559
Oγ	519	519·24	518·74	520
Oδ	481	481·10	480·87	484
Oε	453	452·77	452·87	451

In the harmonic series if we divide the first term by each of the successive terms, we get the partial harmonic progression, $\frac{1}{1}$, $\frac{1}{1.0784}$, $\frac{1}{1.1694}$, $\frac{1}{1.2513}$, $\frac{1}{1.3296}$. The harmonic denominators are equivalent to 1, $1 + 29a$, $1 + 59a$, $1 + 93a$, $1 + 122a$, the first difference ($29a$) being also the final difference ($122a - 93a = 29a$).

The reciprocal series is obtained by multiplying 1·6468 successively by 365·5, 339, 315, 292 and 275. The derivation and significance of the common factor, 1·6468, will be explained below.

The terms in the geometrical series are in geometrical progression.

The arithmetical means between the harmonic and reciprocal values are almost identical with Paalzow's measurements. The greatest difference is less than $\frac{1}{25}$ of one per cent., in Oε. The least difference is $\frac{1}{519}$ of one per cent. in Oγ. The other differences range between $\frac{1}{100}$ and $\frac{1}{320}$ of one per cent.

In previous communications upon spectral harmonies,* I have shown that the Frauenhofer lines of the solar spectrum represent exponential or geometrical values, while the planetary positions represent linear or arithmetical values, in series which are determined by the relations between density and altitude in elastic atmospheres.

I have also shown, elsewhere:† 1. That the collisions of subsiding particles from opposite diametrical extremities of a condensing spherical nebula, tend to form shells, or rings, of nodal aggregation, at $\frac{3}{5}$ of the radial distance from the centre of the nebula.

2. That centres of linear and spherical oscillation exert an important influence, both upon molar and molecular arrangements.

3. That the nodal resistance of large cosmical bodies tends to form other nodal aggregations, at harmonic intervals, in accordance with the laws of musical rhythm which govern the vibrations of elastic media.

4. That there are reasons for anticipating, in the fundamental oscillations of chemical elements, symmetrical harmonic evidences of the same laws as govern the harmonic nodes of elastic media and the harmonic grouping of planetary systems.

5. That in cosmical or molecular aggregation near the foci of paraboloids, there are three wave systems, with tendencies to nodal collisions and the formation of orbits in which the major axes have successive differences of four times the focal abscissa.

6. That centrifugal velocity varies as the fourth power of tangential velocity in a circular orbit.

The distance of projection against æthereal or other uniform resistance is proportioned to the projectile *vis viva*, or to the square of the projectile velocity. The mean *vis viva* of the spherical undulations

* This Journal, October, 1877, p. 284, etc.

† Proceedings Am. Phil. Soc., volumes xii–xviii.

which are generated by Earth's reaction against Sun's action tends, by the laws which govern the moment of inertia, to form a node at ·4 of Sun's distance from Earth, or at ·6 of Earth's mean radius-vector.

According to Dr. Fuhg's estimate,* deduced from 6827 measurements of Sun's apparent diameter, Earth's distance from Sun is 214·524 solar radii, and Neptune's distance is 6442·985 solar radii. Having already seen that the Fraunhofer line A, with a wave length of 7612 ten-millionths of a millimetre, is the exponential correlative of the planet Neptune,† we readily find that Earth's mean reaction against Sun's action may be represented by a wave-length of 4215·8. For, log. 6442·985 : log. ·6 × 214·524 :: 7612 : 4215·8.

If we regard this reactionary value as a fundamental wave-length for terrestrial chemical elements, we may also (by laws 5 and 6) regard $(\frac{1}{4})^4$ of 4215·8 = 16·468 as a fundamental increment for such harmonic undulations as may be excited in an elastic medium by inertial resistance.

We have seen in the foregoing comparative table the influence of this fundamental increment upon the oxygen lines. Multiples of the same increment also appear in the differences between the wave-lengths of other elementary spectra and in Lockyer's "basic lines." Take, for example, Gibbs' groupings of corresponding lines,‡ in Kirchhoff's and Huggins' measurements of the spectrum of arsenic:

Kirchhoff.	Huggins.	Normal.
617·54	617·67	617·54
611·69	611·67	611·69
578·95	578·73	578·75
533·55	533·41	533·55

In the normal column, the shortest wave-length, 533·55 = $2^2 \times 3^4 \times 1{\cdot}6468$; 617·54 — 533·55 = 51 × 1·6468; 611·69 — 578·75 = 20 × 1·6468; the second set is harmonically connected with the first, for 617·54 ÷ 611·69 = 1 + ·009575, and 617·54 ÷ 578·75 = 1 + 7 × ·009575; the only difference between Kirchhoff's and the normal lines is less than $\frac{1}{28}$ of one per cent.; the normal difference is precisely equivalent to Kirchhoff's in the first set, and to Huggins' in the second; the sum of the extreme lines is the same in each column (617·54 + 533·55 = 617·67 + 533·41).

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* Astron. Nachr., 2040.

† This Journal, *loc. cit.*

‡ American Journal of Science, [2], xlvii, 211.

The group of corresponding lines in the spectrum of zinc* exhibits a similar accordance:

Kirchhoff.	Huggins.	Normal.
636·99	637·37	636·99
610·64	610·89	610·64
589·90	589·90	589·55
472·25	471·98	472·31

In the normal column, $636{\cdot}99 - 610{\cdot}64 = 2^4 \times 1{\cdot}6468$; $610{\cdot}64 - 472{\cdot}31 = 84 \times 1{\cdot}6468$; $636{\cdot}99 - 472{\cdot}31 = 10^2 \times 1{\cdot}6468$; $589{\cdot}55 = 358 \times 1{\cdot}6468$. As in the foregoing instance, the sums of the extreme lines are nearly equal in all the columns.

Kirchhoff's copper lines† show a more complicated arrangement:

Kirchhoff.	Normal.
578·67	578·67
529·30	529·27
522·24	522·21
465·64	465·75

In the normal column, $578{\cdot}67 - 529{\cdot}27 = 30 \times 1{\cdot}6468 = a$; $529{\cdot}27 - 522{\cdot}21 = \frac{a}{7} = b$; $522{\cdot}21 - 465{\cdot}75 = a + b$.

Lockyer has published eight "basic lines," which he regards as especially important,‡ and which furnish farther illustrations of these various harmonies, some of which I foretold ten years ago.‖ His lines are given in the following table, together with corresponding theoretical lines, which consist entirely of symmetrical multiples of the fundamental increment:

Theoretical.		Lockyer's Lines.
$(4^4 + 8^2 + 3^2)$	$\times 16{\cdot}468 = 5418{\cdot}0$	5416
$(4^4 + 8^2)$	$\times 16{\cdot}468 = 5269{\cdot}8$	5269
		5268
$(4^4 + 7^2 + 3^2 + 2^2)$	$\times 16{\cdot}468 = 5236{\cdot}8$	5235
$(4^4 + 7^2 + 3^2)$	$\times 16{\cdot}468 = 5170{\cdot}9$	$b^3\, b^4$
$(4^4 + 7^2)$	$\times 16{\cdot}468 = 5022{\cdot}7$	5017
4^4	$\times 16{\cdot}468 = 4215{\cdot}8$	4215

My investigations have been entirely independent of Lockyer's, and

* *Ib.*, p. 212.
† *Ib.*, p. 207.
‡ Proc. Roy. Soc., January, 1879.
‖ Proc. Amer. Phil. Soc., x., 103; xii., 392 sqq.; xiii., 245; xvi., 507

I was not aware until I learned by the announcement of M. Dumas, in the *Comptes Rendus*, that the distinguished English spectroscopist had obtained any results which would confirm my anticipations. There has been, therefore, no possible opportunity for shaping my theory so as to accord with the facts. I simply showed, upon mathematical grounds, what *must be* the tendencies resulting from the mutual action and reaction of well-known forces. None of the evidences, which I have here adduced, were either known or suspected to exist when I published my papers. These accordances, therefore, have a double value, for they furnish the physical proof, which is most satisfactory, of *a priori* conclusions, and they show that Lockyer's theories, in addition to the evidence which convinced his own mind, have the corroborating support of principles which are operative wherever a ray of light can go and wherever a physical action can awake an equal and opposite reaction.

In comparing the two sets of wave-lengths in the foregoing table, we see that, while there is the general accordance which gives the most satisfactory indication of natural law, there is sufficient deviation from precise coincidence to show the desirableness of further investigation, in order to secure the greatest possible accuracy of measurements, and to eliminate the effects of disturbing influences. In two instances theory gives only a single line (5269·8 and 5170·9) to represent two lines or a doubled line in Lockyer's system (5269, 5268, b_3, b_4). I can think of no more probable reason for such doubling than a modification of the other activities by centripetal collisions, in accordance with the first of the foregoing principles. The central line of the five theoretical *incremental* lines (5236·8) represents $\frac{3}{4}$ of the interval between the theoretical representatives of the doubled lines (5170·9 and 5269·8).

Lockyer does not give any estimate of the wave-lengths of b_3 and b_4. Gibbs gives 5177 as the wave-length of the b line. All the theoretical incremental multipliers are integral squares representing thermodynamic increments of *vis viva*, or of inertial moment, which correspond both to increments of temperature and to distance of projection against uniform resistance. The difference between the initial incremental coefficients in the two sets of symmetrical lines ($8^2 - 7^2$) is 15. The greatest square in 15 is 3^2, which is the first supplementary increment of the coefficient in each set; the greatest residual square in 15

-3^2 is 2^2, which is the second supplementary increment in the first set.

The greatest actual difference between the theoretical and Lockyer's measured values ($5022{\cdot}7 - 5017 = 5{\cdot}7$) is only $\frac{1}{4000000}$ of an inch.

This is, however, nearly 35 per cent. of the fundamental increment, a deviation which would materially affect the credibility of the theory if only the simple increment in this single instance were in question. But the deviation is only $\frac{5}{7}$ of one per cent. of the multiple increment, which the law of symmetry requires, ($7^2 \times 16{\cdot}468$), and less than one-eighth of one per cent. of the total wave-length. If we reduce each of the theoretical values about $\frac{1}{875}$ of one per cent., by dividing by 1·00028, the general closeness of accordance will be more readily seen.

Reduced Theoretical.	Measured.
5416	5416
5268	5269
5268	5268
5235	5235
5021	5017
4215	4215

In my paper upon the "Music of the Spheres,"* I showed that the positions of the various primary planets are more accurately represented by these laws of harmonic oscillation than by either of the merely empirical series that have been devised, and even more accurately than by Peirce's phyllotactic series, which comes next to my own in order of precision, and which may also be explained by harmonic tendencies that were pointed out by Laplace in his "Mecanique Celeste." I have since published various confirmations of astronomical predictions,† which it may be well to collect and repeat in this connection, but in order to correct some erroneous impressions in regard to the character of the anticipations and in order to show the remarkable generality of the influences which have justified forecasts in such different fields of investigation, I give below the three known terms on which the prediction was founded, together with eleven subsequent verifications, and one missing term representing a necessary tendency which is mathematically demonstrable and which, I am confident, will be hereafter veri-

* This Journal, September, 1877.

† *Ib.*, Oct., Nov., 1878; March, 1879.

fied. The numerator a represents $\frac{2}{3}$ of Jupiter's semi-axis major, in accordance with the first and fourth of the foregoing principles.

Prediction.		Verification.	
$\frac{a}{1}$	= 3·469	Asteroid 87	3·482
$\frac{a}{5}$	·694	Venus, mean perihelion	·698
$\frac{a}{9}$	·385	Mercury, mean	·387
$\frac{a}{13}$	·267	De la Rue, Stewart and Loewy	·267
$\frac{a}{17}$	·204	Kirkwood	·209
$\frac{a}{19}$	·183	Watson, II.	·180
$\frac{a}{21}$	·165	" I.	·164
$\frac{a}{25}$	·139	. . . .	. . .
$\frac{a}{29}$	·120	Von Oppolzer	·123
$\frac{a}{33}$	·105	Helios	·106
$\frac{a}{177}$	·0196	Themis	·0196
$\frac{a}{321}$	·0108	Eunomia	·0108
$\frac{a}{465}$	·0074	Phaos	·0075
$\frac{a}{609}$	·0057	Lychnis	·0056
$\frac{a}{753}$	·0047	Sun's surface	·0047

It has been urged, as an objection to this series, that the existence of any intra-mercurial planets is still a mooted question. The objection may be answered as follows:

1. My investigations have been limited to the demonstration of *tendencies*. After I had found that the influences of harmonic oscillation were traceable from *Alpha Centauri* to the solar system, and also in the position of all the known planets and satellites within our system, it was evident that those influences do not stop at the orbit of Mercury, but that they must extend to the Sun. There was, therefore, little risk in predicting that evidences of such intra-mercurial activity would be found. This prediction was completely verified when De la Rue, Stewart and Loewy announced the discovery of their sun-spot period, with its alternating northern and southern maxima.

2. Tendencies of one kind are often modified or completely overridden by tendencies of another kind. In view of the many perturbations to which any intra-mercurial bodies must be subject, it is

reasonable to believe that asteroidal aggregations may be alternately formed and broken up, in the neighborhood of harmonic nodes, and even to look for future conclusive evidence of such shifting arrangements of "cosmical dust." No one who knows the ability and prudent cautiousness of Professor Watson can well doubt that the two unknown bodies which he saw during the last total solar eclipse, were either planetary or cometary.

3. The necessity that rotary oscillation should obey harmonic cyclical laws is just as great as the necessity that the oscillations of planetary revolution should be harmonic. Therefore, the discovery that the three known systems of rotation, in the belt of light planets, in the belt of dense planets, and in the sun itself, are represented by the harmonic series which is established by the combined action and reaction of Sun, Earth and Jupiter, furnished three additional and indubitable verifications of prediction (Helios, Themis, Eunomia).

4. The discovery that the node of Herschel's theoretical "subsidence" (Lychnis), is harmonically intermediate between Sun's surface and "Phaos," and that this ternary system also completes a series of co-ordinate harmonic groupings which begin in the region of the fixed stars and end in the sun, furnished three additional and indubitable verifications of predictions.

5. With regard to the four remaining verifications, we may admit that they are less complete than the others; but the simple names of Kirkwood, Mouchez, Gaillot and Von Oppolzer are sufficient guarantees of the fact that planetoid sun-spots and planetary bodies have been seen in positions all of which can be satisfactorily accounted for by the hypothesis of the four harmonic orbits which these astronomers have computed. Whether the spots and bodies were transient or permanent is a matter of no consequence; the fact remains that the indications exist, and the discovery of those indications furnished four additional verifications of prediction. That there are many others in the fields of astronomy, optics, electricity, thermodynamics, chemistry and general physics, I am sure. That many of them will be discovered hereafter I most confidently and unhesitatingly believe.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON OLSEN'S TESTING MACHINE, RIEHLE BROS., MANUFACTURERS.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, May 1st, 1879.

The Sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination, Testing Machines and Appliances for Testing, invented by Tinius Olsen and manufactured by Riehlé Bros., report that these machines are of various designs, adapted to different materials and purposes, with capacities ranging from 1000 lbs. to 300,000 lbs. In most of them the article to be tested is placed so that one end receives the stress from the source of power, while the other end is acted upon by a system of levers terminating in a graduated beam, so that this stress can be accurately counterbalanced and weighed. But in some of the machines one end of the article is held in a fixed abutment, while the power, which is applied at the other end, has its abutment on the weighing mechanism. In other words, the first-mentioned machines have the article placed between the power and the scales, whilst in the last the power is placed between the article and the scales. The stress is produced in various ways in the different machines, according to their capacities. In the small ones, for testing threads, fabrics, cement, wire, etc., a simple screw is used, the nut being revolved by a hand-wheel or lever. As the machines increase in capacity, so the power to produce the stress is increased, as follows: hand-power through bevel gearing to nut on screw, hand-power through worm and worm-wheel to nut on screw, belt-power through bevel gearing or worm and worm-wheel to nut on screw, hydraulic jack with single pump worked by hand, hydraulic jack with single pump worked by power, and, finally, in the large machines, hydraulic jack with triple pump worked by power.

In all of these machines the weighing apparatus consists of a well-arranged system of simple levers supported on ample knife-edges, the whole being convenient to operate, properly proportioned and handsomely designed, and accurate withal.

The especial characteristics of these machines are the design and

invention of Mr. Tinius Olsen, and most of them are fully described in the accompanying copies of recent patents granted to him.

In the patent of March 25th, 1879, No. 213,525, is described some improvements on their 40,000-lbs. vertical machine. A loose cross-head is suspended by long links from the upper tools, and reaches below the lower tools, for the purpose of enabling compression and transverse tests to be made without any change in the machine, and, at the same time, serving as a guide for the lower tools. This is a decided improvement, adding to the convenience and usefulness, without much increasing the cost.

An arrangement is also shown for lifting the jack after a specimen has broken, or to adjust for length. We do not approve of this, for the reasons that, in our opinion, the chain-wheels would cause one screw to lead the other; that it would be a slow process, running the screws down until the pawls engaged with the rods on the jack; that the pawls would prove troublesome and not act well. This arrangement is also intended to hold down firmly the cross-head of the plunger when a specimen is under stress, so as to prevent this stress from being relieved by any leakage from the jack or connections. For this purpose the device is useful.

The general design of this machine is good. It is compact, while, at the same time, the parts are accessible. The jack is worked by a single hand-pump. The beam and poise are in a convenient position, close to the pump and to the tools. One man can make careful tests, as everything is within easy reach. We can commend this as being a useful and handy size and form of testing machine. It is intended for testing specimens cut to a certain size so as not to exceed its capacity.

Patent No. 212,107, granted to Mr. Olsen October 25th, 1878, describes a much larger vertical machine, for testing materials in the actual shapes and sizes used in construction. When practicable, this is a better method, and gives more reliable results. We thoroughly examined a machine of this form of 100,000 lbs. capacity, built for the Pennsylvania Railroad Co.'s shops at Altoona. The arrangement of the platform, levers and jack is remarkably compact, and this, together with the great capability of adjustment of the cross-head carrying the lower tools, enables tests to be made of articles of unusual length. The jack is inverted and bolted to the bed of the machine underneath the platform. This economizes room, but at the expense of convenience for repairs. Instead of a single acting plunger, the jack

has a piston which receives the pressure either on its entire upper surface, for producing the stress, or on its annular under surface, for returning it to position. The pressure is produced by a triple-acting pump worked by belt-power. A rod and hand-lever in front of the platform and immediately below the scale-beam operate the valves, which are so arranged that the flow of the fluid can be shut off without relieving the pressure in the jack or stopping the pump; or the flow can be so directed as to cause the plunger to move in either direction as desired. One man can thus conveniently control the pressure and move the poises without changing position. The location of the specimen is, however, inconveniently high.

A good feature, described in this patent, is that of the adjustable rods, which can be screwed down hard against the cross-head of the plunger, preventing the stress from being relieved by any leakage when the pumps are shut off from the jack for a considerable length of time, as is often desirable; but this does not provide for the relieving of the stress on the specimen occasioned by its own stretching.

Olsen's patent of April 8th, 1879, No. 213,998, describes another form of vertical machine for still heavier purposes. In this case the jack is placed at the top, resting on the weighing mechanism. Its plunger is connected by rods with a cross-head which acts on one end of the piece being tested, the other end of the piece being held by the bed of the machine. The position and arrangement of the cross-heads and tools are very convenient, and long pieces can be readily handled. We regard this as an important feature. The jack, instead of being supported on one main lever, with its fulcrum in the line of strain, in which case it would be in a condition of unstable equilibrium, is made to rest on two levers of different lengths but of the same count, and so placed that the line of strain passes between their fulcrums at distances from each relatively proportional to their lengths. This gives a good broad base to firmly support the jack, and, together with the arrangement of links between the main and intermediate levers, makes an ingenious and efficient construction. Messrs. Riehlé Bros. have never built machines on this plan, but we think it has advantages, and promises to be superior in many respects to the other forms. A drawing of a 150,000-lbs. machine of this style is appended.

Patent of February 25th, 1879, No. 212,734, describes a horizontal machine of 300,000 lbs. capacity, designed especially for testing chain, and built for, and in daily use by, Messrs. Bradlee & Co., of this city.

In this machine the stress is produced by a jack worked by triple-pump driven by belt-power. The jack is at one end of the apparatus and the weighing mechanism and pumps at the other. Heavy timbers are placed between, enabling any length to be obtained, Messrs. Bradlee's machine being about 130 feet over all.

In a horizontal machine of this length and power, special arrangements are necessary to allow for the recoil, both of the jack and of the main weighing levers, which occurs when a heavy chain or other article breaks under strain. This has been well provided for by the devices described in the patent.

Your committee visited Bradlee's chain works, saw the machine in practical use, and tested in it a chain having links made of 3¼-inch round iron, on which was put a strain of 300,000 lbs., the full capacity of the machine. The result was very satisfactory, although, when at its maximum, the machine began to show signs of effort, and could hardly be recommended for continuous work of so great severity.

The triple pump, used to work the jacks of this and other machines, consists of three single-acting plungers, which receive motion, through walking beams, from three cranks at angles of 120 degrees with each other, the objects being to give a steady supply of fluid to the jack and to avoid blows. The stroke of these plungers is made adjustable, so as to vary the power and speed to suit the nature of the test being made. This is accomplished by changing the position of the fulcrums of the walking-beams, as follows: A sliding frame, moved by a screw and hand-wheel, carries a shaft on which are fitted three boxes, each of which has a flat top and bottom fitting between the two halves of the walking-beam, after the manner of the locomotive slide-link. One end of each walking-beam is journaled to a crank, and the other end is connected by links to a plunger. It is evident that when the shaft, which is carried by the sliding frame, is central between the two ends of the beam, the stroke of the plunger will be equal to the entire throw of the crank, or to double its radius. If the frame be moved toward the pump end, this stroke will be diminished, and *vice versa*. As this adjustment can be made without stopping anything, it forms a very convenient and effective arrangement. There is considerable slide of the walking-beams on the fulcrum boxes, owing to the fact that one end of the beams receives a rotary motion from the cranks. This produces an amount of friction that is very noticeable under heavy strains, and which could be suitably provided for by a proper amount of surface.

Olsen's patents of March 25th, 1879, No. 213,525 and No. 213,586, describe tools for holding the ends of specimens while being tested for tensile strength. We did not see either of these in practical operation, but it is claimed that they are a decided improvement on the old methods. We rather question the advisability of making the tool to act as an universal joint, for in case the axis of the test piece were out of line with the axis of stress, this arrangement would be apt to do more harm than good. What is wanted is a device that will infallibly grip each end of the piece so that its centre-line corresponds with the centre-line of pull. The feature of allowing the wedges to accommodate themselves to any irregularities is proper, but the tool should also fill the conditions named above.

The various forms and sizes of testing machines designed by Mr. Olsen and manufactured by Messrs. Riehlé Bros. really constitute a new industry in this country, and particularly in this city. Messrs. Riehlé Bros. have undoubtedly increased the interest in, and desire for, more extended data as to the qualities of materials. They have placed within the reach of manufacturers good, practical and reliable means of ascertaining these qualities, and it is to be hoped that their efforts will tend to aid the continual improvement of our products, and thus be of great service in the advancement of our mechanical industries.

Although we may criticise some of the details of their machines, and may, in some cases, see room for improvement in workmanship, yet we heartily commend their aims, and think they deserve great credit for what they have already done and are now doing.

Respectfully submitted.

Wm. H. Thorne.
L. R. Faught.
J. Haug.
Joseph Zentmayer.
Wm. D. Marks.

Improved Vulcanized Rubber.—C. Schwanitz, Jr., of Berlin, uses glycerin in the preparation of vulcanized rubber, in order to secure it from injury by fats and oils. He also passes the finished mass between warmed rolls, in a glycerin bath, in which it is exposed to steam, under a pressure of two or more atmospheres.—*Dingler's Journal.* C.

MACHINES FOR MEASURING.*

By GEORGE RICHARDS, Philadelphia.

Niceties of measurement, beyond the limit of one-thousandth of an inch for example, are often looked upon by practical men as experiments not required in ordinary practice. This is, however, a mistake, because one-thousandth of an inch is far within a dimension which workmen continually use. One ten-thousandth of an inch, as a term, seems an abstraction, in practice it is a tangible quantity to be felt, seen and demonstrated.

In a paper read before the Institute of Mechanical Engineers in 1857, at Manchester, Mr. Whitworth said: "In the manufacture of my standard gauges of size, the workmen measure to the $\frac{1}{20000}$ of an inch, and these measures are as familiar and appreciable as those of any larger dimensions," so that a machine to record sizes to within the one five-thousandth of an inch, and for comparative tests to one ten-thousandth of an inch, such a one as is shown here this evening, is in every sense a practical working implement.

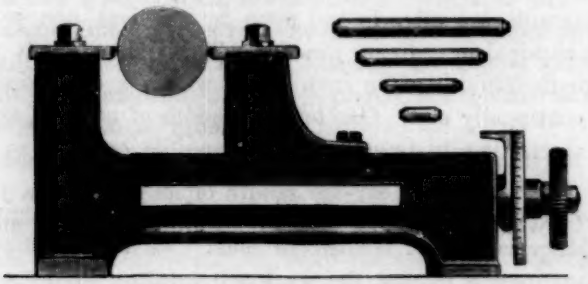
There has arisen a kind of romance in connection with accurate measurements, which is, no doubt, attributable to the secrecy observed in the preparation of gauging tools, perhaps also, in some degree to the nice experiments of Sir Joseph Whitworth showing that one-millionth part of an inch could be indicated, not measured, as was claimed, by one of his machines. The difference between measuring and indicating must always be kept in view when dealing with machines for determining and comparing dimensions.

In making gauging tools, it was at first expected that dimensions could be transmitted from one measuring machine to tools in process by means of carefully adjusted gauges, pins and so on, but it soon became apparent that in order to adjust gauges there must be some means of showing how they approach the finished size, and this applies not only to the last or finishing processes, but also to preliminary ones as well, where allowance has to be made for the distortions and shrinkage of tempering, grinding and so on. By experience the work-

* Extracts from a paper read before the Franklin Institute, April 16th, 1879.

men learn whether one, two or ten "divisions" are enough to allow, and work accordingly. The division meaning one ten-thousandth of an inch by the scale employed on our working machines.

This same system is applicable, as we now think is almost a necessity, in preparing ordinary tools, such as mandrils, reamers, screw taps, and so on. This view has led to the preparation of the machines, one of which is shown here this evening.



Calipering and Measuring Machine.

This little machine, only twelve inches long, has been contrived in such a manner that it will indicate to one ten-thousandth of an inch, or measure absolutely to one-thousandth of an inch or even less if required, and yet it is furnished at a small expense.

It was foreseen that such machines would prove of value in tool-rooms where standard and special tools are continually being prepared. The machine would enable gauges or other exact tools to be made, and at the same time answer the further purpose of keeping gauges of all kinds to standard sizes by detecting wear or derangement. The machine consists of a frame having a sliding stock moved by a screw. On both the frame and sliding head are fixed hardened steel points. The points have been, from experiment, found best when made wide, with double bearing points. This prevents the machines being forced by over pressure.

The screws for moving the points are of course an important part of the machine. These screws are brought within a limit of one in two thousand for accuracy. With each machine is furnished four hardened steel test pins or rods, one inch, two inches, three inches and four inches. These are adjusted, at a temperature of from 70° to 75°, by the standard measuring machine. By employing these pins as starting tests it is evident that in no case will the truth of the screw have to be relied

upon for a range exceeding one-half an inch. I may mention that we are now engaged in experiments to determine some inexpensive mode of correcting the screws of their error, although for all practical purposes this may seem superflous.

We usually furnish with each machine a table of the screw's errors, so that any one who is curious in the matter can make absolute measurements.

The machine is arranged with an index wheel on which there are marked one hundred divisions, each representing one-thousandth of an inch at the points. Beside, and almost in contact with this index wheel, is a moveable or adjustable pointer. Now, assuming the error, in any case, to be one in two thousand, then, if a half inch is to be measured, the index or pointer is moved forward or back one-fourth of a division, or to make one four-thousandth of an inch at the points.

Screws grow gradually shorter as they are reproduced and their errors are greater than is expected.

As a matter of interest those pres nt who themselves have not investigated, I will now recount some of the principal facts in the derivation of our lineal measures.

In the time of William the Conqueror, it was ordained by statute in England that "the measures and weights shall be true, and stamped in all parts of the country." The standards of weight and measures were deposited in a special building, just as the standards of ancient countries were placed in their temples. The existing imperial yard is so nearly identical in length with those old standard yards of Henry VII. and Queen Elizabeth that it exceeds them by little more than a hundredth part of an inch, a difference frequently found in rules and scales now commonly used. It is also curious to note that the English foot is nearly identical with two-thirds of a natural cubit, known as the *ancient* foot. A double cubit was used in ancient times as a measure of length, and an old Egyptian double royal cubit, found in the ruins at Karnac, may be seen in the British Museum at London. A measure very near equal to two natural cubits was used by the Romans under the name of *ulna* or ell. The *ulna* is mentioned by Pliny, when describing the measurement of the girth of a tree as half the length of the extended arms of a man. It may be fairly assumed that the measure of the double natural cubit, or three feet under the name of *ell* or *yard* came into use in old times as a very convenient measuring unit and found its way into England as the standard unit of length.

The primary standards of weights and measures in England were destroyed by the burning of the houses of Parliament in 1834.

The legal standard unit of measure in England was constructed under the superintendence of the Standards Commission, appointed in 1843, for the restoration of the lost standards.

The act of 1824 under George IV., under the authority of which the lost standards had been legalized, directed that in the event of their loss or destruction new standards should be constructed in accordance with permission contained in the act, by reference to an invariable *natural* standard. After long deliberation the commission made a report stating that to base the standard of measure upon pendulum vibrations was doubtful and erroneous.

They recommended that no change should be made in the unit of measure. A committee of scientific men were appointed to construct a standard by comparisons with the most carefully selected specimens. The magnitude of the operations may be estimated from the fact of the number of micrometer readings for all the comparisons, exceeding two hundred thousand, and amongst the operations it was found necessary to construct an entirely new system of thermometers.

These labors extended over a period of twelve years, and the new standards were legalized in 1855. In order to select the most perfect specimen for the new standard of length, forty line standard yards were constructed, and one of these was finally selected as the imperial standard, not only from its representing, with the greatest precision, the *assumed* length of the last standard yard, but also from the clearness of its defining lines and from its general good workmanship.

A copy of this was then obtained by the standards department at Washington, from which to reproduce duplicates for each State.

Mr. Saxon, then connected with the department, arranged devices for comparing both line and end standards. More ingenuity and care was shown in Washington, perhaps, than ever was before exercised in any country in preparing these comparing devices. Mr. Saxon used a comparing machine, which the members may have seen in the government building at the exhibition in 1876, indicating to millionths of an inch.

In order to magnify the differences of bars, he employed a mirror, arranged to vibrate and be read on the segment of a large circle. In order to avoid tedious labor, he adopted an ingenious plan of marking

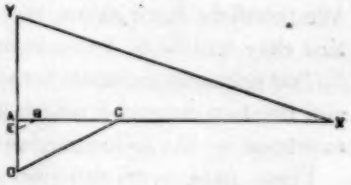
the standards at different temperatures, to allow for differences in length, the range being from 68° to 72° or thereabouts. The expansion of a standard yard, when placed in the instrument and the finger placed near it, is readily seen in the readings.

APPROXIMATE QUADRATURES OF THE CIRCLE.

By Pliny Earle Chase, LL.D.

Some of the European technical journals have lately given graphic approximations to the ratio of the circumference to the diameter of a circle. Neither of the solutions, which have fallen under my notice, is so simple or so close as the following:

On the rectangular co-ordinates X, Y, lay off, from a scale of equal parts, $AB = 3$, $AC = 20$, $AX = 60$, $AD = 9$. Join DC and draw BE parallel to DC. Take $EY = AC$, and join XY. Then $XY : AC$: : circumference : diameter, *very nearly*.



For if $AC = d$, $AB = \frac{3}{20}\,d$; $AE = \frac{3}{20} \times \frac{9}{20}\,d = \frac{27}{400}\,d$; $AY = \frac{373}{400}\,d$; $XY = \sqrt{9\,d^2 + (139129 \div 160000)\,d^2} = 3{\cdot}14158499\,d$. The true ratio is 3·14159265, differing by less than $\frac{1}{4100}$ of one per cent. from the graphic approximations, which would give an error of less than $\frac{1}{6}$ of an inch in a mile. The approximate circumference $X'Y'$, for any other diameter, AC' may be found by taking $AX' = 3AC'$, and drawing $X'Y'$ parallel to XY.

The simplicity of this construction is no greater than its practical adequacy. This fact will become evident upon considering that, in graduating a circle of three feet radius, the error for a single degree would be less than $\frac{1}{650000}$ of an inch. In spacing gears with teeth, six inches apart, the error would be less than $\frac{1}{65000}$ of an inch.

Haverford College,
June 16th, 1879.

THE ELECTRIC ARC—ITS RESISTANCE AND ILLUMINATING POWER.

By Profs. Elihu Thomson and Edwin J. Houston.

From a series of investigations made by us in the winter of 1877–78, and published in the Journal of the Franklin Institute for May and June, 1878, as part of a report of the Committee of the Franklin Institute on Dynamo-Electric Machines, we were led to infer the existence in the electric arc of certain relations between resistance, current strength and illuminating power. Further experiments in the same direction have seemed to confirm these relations. We therefore have taken the opportunity of stating them, believing that they will be of value to other investigators in this field.

The relations existing between arc resistance and current strength, and between current strength and illuminating power, are apparently expressed by the following laws, viz.:

First. *In arcs of equal lengths the resistances are inversely proportional to the current strengths.*

Second. *The illuminating power of an arc is approximately proportional to the current traversing it.*

Third. *In arcs of equal length the total energy given out is proportional to the current strength.*

Whether the above laws will be established for great range of conditions remains for future investigation; and, indeed, when it is considered that it is almost impossible to maintain arcs of equal lengths, the results may be regarded as approximately true, and point to the need of an extended series of experiments, in order that the errors in individual cases may be eliminated. The experiments we are now conducting in this direction are not yet complete, and embrace, besides the laws just stated, other interesting relations. We have thought, however, that the results thus far obtained justify the publication of the above statements of existing relations.

The following theoretical considerations, aside from experimental data, serve partly to explain the first law. An increase of current is attended by a more active transferrence of carbon vapor from positive

to negative electrode, which would result in an increased breadth of arc and, consequently, decreased resistance.

The bearing of this law on the question of the economical division of the electric current in the production of several arcs in the same circuit, instead of one single arc, is important. It has been held by some that if the intensity of the current be halved, the work being as the square of the current, economic division is impossible. It must not, however, be forgotton, as appears to have frequently been the case, that the above statement assumes that the resistance is constant. With the arc, however, the resistance with a changed current is not constant. If the current be doubled, its resistance is halved; if the current be halved, its resistance is doubled — always assuming the distance between the electrodes to remain constant. The work of the current, therefore, with a given length of arc, is proportional to the current, and not to the square of the current, as has been frequently assumed. The third law expresses this relation, the total energy being the work given out as light and heat, and due to current traversing resistance, which resistance falls as the current increases, and the converse.

The total energy evolved in an arc does not, however, appear to be a measure of the illuminating power of said arc, it having been noticed by us that the total energy in the arc may be the same, while the illuminating power varies considerably. The illuminating power of arcs representing equal amounts of energy evolved, appears to be affected considerably by the distance apart of the carbon electrodes. It is found in practice that, in any case, the maximum illuminating power is obtained when the electrodes are separated to a certain distance. An increase of this distance between the electrodes is attended by an increase in the resistance of the arc and by a decrease in the current strength, not, however, proportional to the increased resistance. Consequently, an increase in the total energy evolved in the arc may take place while an actual decrease of the illuminating power has resulted. This last statement may at first appear to involve a contradiction, but when it is remembered that the greater portion of the light evolved by an arc comes from the intensely heated surfaces of the electrodes, and not from the heated gas stream constituting the arc proper, it can readily be understood that with a large arc, a considerable proportion of the energy will be expended in sustaining the temperature of the gas stream and supplying or making good the heat convected from it to the surrounding air. In an arc of less length, a smaller proportion of the

energy is expended in sustaining the temperature of the gas stream, and the amount of surface of the electrodes heated to intense incandescence is relatively increased.

It is our opinion that the relation between the illuminating power and the current, as expressed by the second law, is necessarily quite approximate, since the distance apart and consequent facility for loss of heat by convection from the electrodes cannot be without influence on the illuminating power.

CENTRAL HIGH SCHOOL,
Philadelphia, June 13, 1879.

ON AN OSCILLATING AND PORTABLE MELTING FURNACE USED IN FRANCE.

By R. GRIMSHAW.

It is strange that attention has not been earlier called to the crude and wasteful manner of mounting and using crucibles for melting and pouring steel and brass. A hundred years has done little or nothing towards changing this part of the constructor's plant. There is everywhere the same mass of brickwork, with cavities lined with refractory brick; a flue at one side leading to a chimney, a grate below, a cover above, and constituting the "natural draft" melting furnace. Suppress the flue and chimney, and add, below the grate, an air blast-pipe, and there is obtained a higher temperature and quicker melting; but in both, the handling of the crucible is the same faulty and dangerous process.

The crucible must be well centered in the fire-place; firmly bedded, lest it tip to one side or the other. The grate-spaces must be kept free from clinker, as the slicing iron is wasteful of fuel and dangerous to the pot. When the metal is melted and ready to pour, skill is required to remove the coke from about the pot, which is then carefully lifted with special tongs, carried to the mould and used to pour from. If there is over seventy-five pounds of metal it takes two men to handle it. The tongs and the air, especially the latter, cool the crucible, so that often the metal is not hot enough for a proper pouring, and when several castings are made from one potful the last is generally run cold. If the pot breaks while being carried, there is loss of metal, risk to the

men, and often moulds spoiled.* Supposing that all goes well in pouring, and the cooled crucible is to be returned to the broken up fire, there is waste of fuel in getting started up again, and of time in arranging. As regards consumption of fuel, founders count fifty pounds of coke, for one hundred pounds of brass, as a minimum; some even say weight for weight. In steel, about three to four times the weight of fuel is often required, and the heats are only say three to four per day of twenty-five pounds each.† For brass, fire-clay pots last a day, say ten to twenty-one runs; graphite gives thirty to forty heats. For steel, graphite pots give on an average six heats before giving out; clay pots stand three heats in twelve hours, averaging 110 to 130 lbs. for the three heats, and are then done.

Now why should the crucible be withdrawn from the bed of coals at each pouring, causing the risk of considerable loss of heat, perhaps burning the workman, and certainly subjecting him to a heat which increases his discomfort, lessens his possible work and causes him to demand extra high wages? Outside of this, breakage of the crucible is a source of loss of metal. Why waste time and fuel in rebedding the pot in the coke for the next melting?

Why not put up crucible and furnace together and keep the metal hot, while saving all the annoyances above mentioned?

The "Oscillating and Portable Melting Furnace," invented by Mr. A. Piat, one of the most important founders and machinists in France, is designed to obviate all these inconveniences, and from personal inspection of its working in his foundry, 85 rue Saint Maur, Paris, I think his claims not altogether unfounded.

The furnace proper is a boiler-iron case, lined with refractory material, and made square so as to save coke; the fuel mostly lodging in the corners and the pot nearly touching the sides. A strong iron band surrounds the case at such a height that it may tip and balance nicely when the pot is about full of metal. By means of these trunnions the furnace is lifted and carried about; levers or carrying bars being employed in case it is carried by men, a crane being employed for the larger sizes. In some of the large furnaces, the device is tipped only

* While a clay pot is tough at steel melting heat, a graphite pot is brittle at any heat and liable to crush with the pinch of the tongs.

† Messrs. H. Disston & Sons use graphite pots No. 50, three heats in thirteen hours, making 425 lbs. of steel for each crucible when worn out, the pots averaging six heats. For melting, they use best Lehigh anthracite coal, 235 lbs. to each 100 lbs. steel melted.

and seldom carried out of place, the metal being run into an ordinary ladle. The refractory lining is of best fire-brick or of well-tamped fettling. The furnace is slightly conical below. On the front side is a pouring hole and spout. At the back there is a large square opening for escape of the gases of combustion. The cover is that ordinarily used in foundries.

So much for the furnace proper. The crucible, which must be fixed therein steadily and permanently, is supported by a "cheese" or flat cylindrical block of refractory material resting on the grate; the spout which connects the front or mouth of the crucible with the pouring orifice of the case, and a wedge also of refractory stuff placed at the back of the pot and holding the whole firm and central. After the first heat or so these pieces become a unit with the pot.

The whole affair rests on two brick supports and receives a blast-pipe below if blast is used. The grate is cleaned every two or three heats by tipping the whole affair and slicing from below.

For brass melting these furnaces are made up to four hundred and even six hundred pounds crucible contents.

For steel and for running pieces over seventy-five pounds weight, the intention is to have a special furnace placed beside other and smaller ones, to receive their contents and carry them to the place of pouring.

For the larger sizes, time is gained and fuel still further saved by adding a recuperator, heating the blast by the escaping hot gases of combustion.

Referring to the annexed engravings, Fig. 1 represents one of the ordinary smaller furnaces mounted upon a special truck or traveling crane, designed to carry it from place to place and tip it, there being a carriage with traverse motion on the truck to enable pouring to be easily accomplished. It will be seen that the pouring is done from an extra pair of trunnions, so placed as to make the stream fall steadily in one place, even while the whole device moves through a large arc.

Fig. 2 shows in section a furnace for thirty to one hundred and fifty kilogrammes of metal, with forced blast and with recuperator.

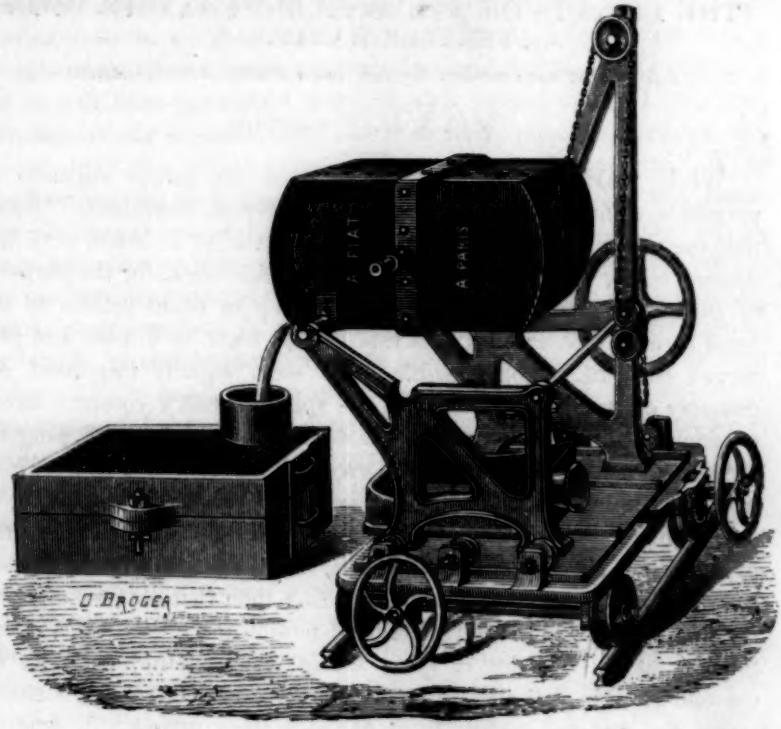


Fig. 1.

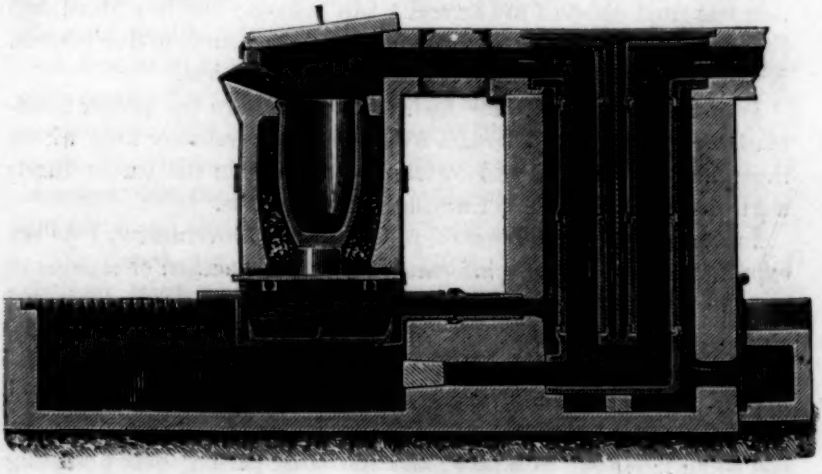


Fig. 2.

THE EFFECTS OF ATMOSPHERIC CHANGES UPON TEXTILE BANDS.

A paper read before the New England Cotton Manufacturers' Association.

By C. J. H. Woodbury.

While making some experiments upon the power requisite to operate a spinning-frame under certain different conditions, I found that the power required to drive the frame varied so much with the tension of the bands, that this varying circumstance, for the purposes of experiment, must be eliminated by having an equal tension to the band turning each spindle, that this tension must be known and preserved constant. These requirements seem equally important for economy of production. To turn the spindles with a constant band-tension just sufficient to produce the desired twist without slipping on the whirl, and, on the other hand, avoiding an excessive stress which would cause unnecessary friction, I believe would lead to a saving of power greater than that claimed by any spindle-maker for his spindle over those of his competitors. That is, the difference of power, caused by correct and false band-tension, is greater than that between any two rival spindles. By weighing the band-tension in various mills, it was found that the practice of tying bands lacked uniformity. As an example of this variation, in one mill the bands on a single coarse frame are reported to vary from one to sixteen pounds; in another mill, on finer work, taking a number of spindles at random, the variation was from one-half to two and a half pounds; and in a third mill the band-tension was between the limits of one-fourth to five pounds. Now this haphazzard method seems hardly mechanical.

Is it not worth while for each spinner to learn the proper band-tension required for his special work, and then endeavor keep within those limits? The changes constantly occurring in the cotton bands used present an obstacle to carrying out these plans.

In accepting the invitation of your Board of Government, I do not expect to impart any new information upon the question of changes in length of bands, except so far as to give matters of detail connected with accurate measurements of these alterations in a number of bands. These measurements were taken by the following method. Two upright posts were firmly fastened against the wall, about ten feet from each other; the samples of banding were extended between these, one end being fastended to a hook, and the other passing over a leading pulley to a weight. In order that the fibre of which these bands were

composed should be free as possible to expand and contract, it was desirable to use a light weight. By experiment, I found that with a weight of two and a quarter pounds the band deflected only one-tenth of an inch from a straight line. A scale against the wall connected the tops of the upright posts, and a sliding framework carried two plumb-lines (fine wires), hung at right angles, to the banding. When the samples had been under tension of the weight about two hours, this framework was slid, until the wires coincided with the division one hundred inches on the scale; then the corresponding length was marked on the banding with red cotton, and this point, also one hundred inches from the extreme end of the sample, was used to measure the dilation in length, by sliding the framework until the plane of the wires coincided with the mark, then reading the distance on the scale above. In this manner I have taken about forty-five hundred readings, all of which were measured upon the same scale, and under equal conditions of accuracy, during a period of three and half months. The apparatus was simple and rude in general construction, but it was sufficiently accurate to indicate a variation of less than one-fiftieth of one per cent. in the length of the samples of banding.

It must not be understood that by this method I assume to reproduce the exact circumstances to which a spinning-band is subjected when in operation, but simply to maintain the bands subject to a constant tension, under the conditions given above, which being applied in an identical manner to each sample, yield comparative results, giving the correct relations of these samples to each other when acted upon by the same specific causes.

A wet bulb hygrometer hung near the banding, and the readings were noted whenever a measurement of banding was taken. From the comparison of the relative humidity, temperature, pressure of the vapor in the atmosphere, and grains of water per cubic foot of air, it was observed that the changes varied with the differences of the relative humidity, and also increased with the continual tension of the weights.

We "took the weather as it came," until the twenty-third of January, when we endeavored to reproduce the conditions of a dog-day, by admitting steam into the room, until the desired humidity and temperature were obtained. Although the temperature was not in excess of that frequently reached, yet the effect of the moisture made the room seem much warmer, and swarms of insect life threw off their winter torpor, and issued from the cracks in the floors. This moist atmosphere caused all the bands, except the one with the linen core, to

stretch. On the 26th of March the same experiment was repeated with similar results. With slight increase of humidity, the bands contracted very slightly, and with large increase of humidity, the same bands stretched.

Moisture, causing cotton fibres to expand laterally, shortens the length of the fibre by increasing its twist; if by excessive moisture the twist is increased largely, the fibres would be freed from the interlocking of the convolutions to such an extent that, if there was a tension upon the whole cord, it would be lengthened by the slipping of the fibres upon each other. On the other hand, if the band had been stretched to the limit of elasticity, the fibres would be drawn in such close union that they could not separate easily, and only the contracting effects of moisture would be shown, without being followed by excessive stretching. With different textiles, these changes would cause variation to the extent that the adhesion of the fibres to each is changed by alterations in their diameter.

Mr. Edward Atkinson suggested that an absolute band might be obtained by combining different fibres in a proper manner. It was considered essential that the outside of the band should be of cotton, as this seems to be the only substance used for textile bands, which does not polish long before worn out. Two bands of this description were made, with cotton braided outside, one of them with linen and the other with worsted core. This method of combining the two fibres I believe to be original with Mr. Atkinson. Cotton and linen have been twisted together by others, but such combination does not wholly accomplish the object, as the linen seems to lack sufficient resistance to check the stretch of the cotton, when the linen threads are twisted among the cotton. I have been informed that cotton and linen bands have been successfully used for wet-twisting by Mr. T. Merrick, of Holyoke. Mr. Edward Kilburn writes that worsted bands were once used for cotton-spinning at Lonsdale, and resulted in a saving of one-sixth of the power until the expiration of about two months, when they became so polished by wear that it was necessary to take them off.

In three months and a half the linen-core banding stretched one per cent. and cotton banding five per cent. The daily results given are the average of a number of readings.

Your attention is called to the fact, that, while the band with worsted core changes in coincidence with the variations of the relative humidity of the atmosphere, the band with linen core changes in an inverse manner.

Measurements of Textile Bands under constant tension of two and a quarter pounds.

1879.		ATMOSPHERE.				COTTON BRAIDED BANDING.						
DATE.		Temperature, Degrees.	Relative Humidity.	Vapor Tension In. of Mercury.	Water per c. foot, Grains.	Linen Core.	Worsted Core.	Cable, no treatment.	Braided, no treatment.	Treated with Naphtha.	Treated with Paraffine.	Made into Parchment.
Months.	Days.											
1	2	3	4	5	6	7	8	9	10	11	12	13
						Percentage of Increase in Length.						
January	2	63·0	·43	·27	2·98	·18	·32	·45	·54	·54	1·72	·83
	3	59·5	·31	·16	1·85	·35	·20	·63	·78	·80	2·12	1·21
	4	61·8	·35	·19	2·27	·38	·25	·78	·86	·79	2·10	1·30
	6	67·2	·36	·26	2·99	·30	·31	·75	·87	·87	2·06	1·33
	7	69·6	·36	·26	3·04	·35	·28	·80	·90	·90	2·28	1·40
	8	65·4	·36	·23	2·66	·30	·31	·80	·90	·90	2·70	1·40
	9	55·6	·55	·24	2·79	·12	·47	·75	·81	·81	3·03	1·40
	10	70·0	·37	·28	3·18	·34	·35	·98	1·08	1·06	2·99	1·67
	11	69·0	·35	·25	3·22	·38	·37	1·03	1·15	1·08	2·87	1·76
	13	69·0	·42	·30	3·46	·31	·40	1·03	1·14	1·07	3·09	1·79
	14	68·3	·40	·28	3·23	·41	·42	1·00	1·14	1·05	3·47	1·80
	15	69·3	·33	·23	2·70	·39	·37	1·08	1·19	1·13	3·40	1·90
	16	67·0	·32	·21	2·40	·40	·34	1·12	1·23	1·17	3·54	1·90
	17	75·0	·29	·26	2·93	·43	·38	1·06	1·22	1·16	3·41	1·95
	18	70·7	·35	·31	3·57	·36	·46	1·06	1·22	1·13	3·55	1·90
	20	69·0	·44	·21	3·99	·31	·48	1·05	1·18	1·12	3·70	1·93
	21	63.5	·37	·22	2·54	·44	·37	1·14	1·28	1·17	3·94	2·00
	22	61·6	·44	·44	2·80	·39	·48	1·16	1·28	1·21	4·08	2·01
	23	73·2	·72	·49	6·55	·07	1·01	1·43	1·47	1·27	3·79	2·42
	24	67·0	·46	·30	3·43	·40	1·14	3·78	3·54	2·34	4·12	4·80
	25	68·0	·47	·22	3·68	·60	1·03	3·93	3·70	3·14	3·98	4·98
	27	67·0	·35	·34	2·69	·63	1·14	3·98	3·79	3·20	4·27	5·09
	28	70·3	·42	·21	3·54	·58	1·28	3·92	3·80	3·20	4·15	5·04
	29	63·0	·42	·24	2·76	·60	1·28	3·99	3·82	3·23	4·65	5·05
	30	72·0	·34	·29	3·34	·67	1·19	4·05	3·94	3·36	4·42	5·19
	31	66·6	·40	·26	3·30	·69	1·25	4·04	3·94	3·38	4·68	5·12
February	1	70·3	·39	·29	3·35	·68	1·21	4·05	3·91	3·40	4·60	5·21
	3	67·5	·36	·24	2·84	·70	1·21	4·10	4·00	3·40	4·83	5·22
	4	69·0	·41	·29	3·39	·71	1·22	4·10	4·00	3·44	5·02	5·20
	5	70·0	·43	·32	3·61	·71	1·23	4·11	4·00	3·46	4·93	5·22
	6	72·7	·41	·29	4·79	·70	1·30	4·10	4·00	3·45	4·91	5·22
	7	67·0	·37	·24	2·76	·71	1·25	4·10	4·01	3·47	5·22	5·25
	8	73·0	·34	·27	3·12	·72	1·17	4·16	4·04	3·49	5·04	5·30
	10	69·0	·38	·28	3·23	·76	1·18	4·18	4·04	3·52	5·21	5·31
	11	72·0	·36	·28	3·27	·78	1·23	4·14	4·02	3·50	5·13	5·31
	13	71·0	·41	·31	3·55	·70	1·32	4·10	4·12	3·55	5·40	5·40
	18	69·0	·45	·32	3·68	·73	1·39	4·18	4·15	3·63	5·64	5·38
	19	63·0	·38	·22	2·59	·76	1·35	4·23	4·20	3·69	5·89	5·42
	20	69·6	·37	·27	3·10	·81	1·34	4·21	4·21	3·69	5·77	5·44
	21	65·5	·33	·22	2·49	·87	1·30	4·27	4·25	3·73	5·82	5·48
	24	50·0	·45	·16	1·89	·70	1·40	4·24	4·23	3·72	6·10	5·46
	25	71·0	·33	·25	2·92	·90	1·27	4·32	4·30	3·79	5·70	5·49
	26	72·0	·38	·30	3·43	·90	1·37	4·27	4·27	3·78	5·70	5·50
	28	67·6	·38	·26	3·04	·97	1·31	4·33	4·33	3·85	5·87	5·54
March	15	64·3	·37	·23	2·66	·90	1·38	4·29	4·29	3·87	8·65	5·58
	17	65·0	·45	·28	3·24	·85	1·51	4·26	4·31	3·83	8·68	5·55
	18	68·0	·39	·27	3·08	·89	1·44	4·33	4·32	3·87	8·63	5·57
	20	65·0	·44	·27	3·08	·91	1·45	4·31	4·40	3·91	8·83	5·59
	21	61·3	·51	·28	3·26	·79	1·55	4·22	4·29	3·80	8·80	5·52
	22	65·6	·49	·33	3·78	·82	1·52	4·24	4·31	3·81	8·71	5·54
	24	69·0	·50	·38	4·29	·78	1·55	4·21	4·27	3·79	8·49	5·53
	25	68·5	·48	·34	3·87	·79	1·54	4·20	4·29	3·80	8·66	5·53
	26	73·9	·79	·68	7·48	·12	1·53	4·09	4·29	3·85	8·41	5·61
	27	71·5	·51	·41	4·52	·59	1·45	4·66	4·82	4·59	8·45	6·25
	28	69·0	·46	·33	3·81	·76	1·40	4·79	4·90	4·60	8·67	6·34
	29	69·3	·49	·35	3·99	·76	1·44	4·80	4·92	4·61	8·74	6·37
	31	68·5	·45	·30	3·43	·80	1·42	4·83	4·92	4·62	8·75	6·39
April	1	65·0	·42	·26	3·00	·84	1·39	4·90	4·90	4·65	8·84	6·44
	2	68·0	·40	·28	3·17	·92	1·37	4·93	4·97	4·71	8·73	6·48
	4	66·0	·35	·22	2·60	·99	1·35	5·01	5·02	4·76	8·98	6·52
	5	64·7	·43	·26	3·02	1·00	1·39	4·99	5·02	4·75	8·93	6·51
	7	66·0	·45	·29	3·34	·96	1·46	4·93	5·00	4·72	8·91	6·50
	8	67·0	·44	·29	3·38	·99	1·41	4·99	5·00	4·77	8·88	6·50
	9	66·0	·45	·29	3·32	1·00	1·44	4·95	5·00	4·77	8·95	6·50

A COMPARISON OF THE PERCENTAGES OF PHOSPHORUS IN BITUMINOUS AND ANTHRACITE COALS.

By C. Henry Roney, C.E.

In many metallurgical operations a fuel practically free from phosphorus, as well as sulphur, has been considered a desideratum, and in 1869, being interested in iron ore and coal deposits in both Eastern and and Western Pennsylvania, it became necessary for me to determine the percentages of both elements in samples of anthracite coal as shipped to market from some of the collieries of Schuylkill county, particularly as the statement had frequently been made that our Schuylkill anthracites contained injurious amounts of one or both these elements, while the bituminous coals, it was claimed, were comparatively free from both, and were further improved by the coking to which they were subjected before use, as a large part of the sulphur was driven off by that process. I made a series of analyses which satisfied me that most of our leading Schuylkill anthracites, if carefully prepared, picked and screened free from slate, "bony" coal, etc., contained scarcely a trace of phosphorus, but that when carelessly mined and prepared they might contain injurious amounts of that element as well as sulphur. In coking bituminous coal, as little or no phosphorus would be driven off with the volatile bituminous matter, the percentage in the coke would be greater than in the coal from which it is made, the yield of coke by weight being from twenty to forty per cent. that of the coal, depending on the character of the coal and the process of manufacture, although the increase in bulk may be about twenty-five per cent.

In the manufacture of pig iron, with the blast-furnace in good working order, with an acid slag carrying very little iron, very little or no phosphorus is carried off in the slag, as the conditions which favor the perfect reduction of the oxides of iron to the metallic state likewise favor the reduction of the phosphoric acid, which then combines with it, remaining in the pig iron in place of combining with the slag and being removed with it, whether derived originally from the iron ore or fuel; the same process takes place in the Bessemer converter, with a siliceous (acid) lining, and has been one of the chief difficulties with which it has had to contend, as the phosphorus in the

pig iron has not been removed during the process of decarburization but has remained in the steel. The recent announcement of Messrs. Thomas and Gilchrist's process of dephosphorizing iron in the Bessemer converter by the use of a "basic" lining, with which the phosphoric acid can combine and thus be removed from the iron, permitting the use of iron ores containing large percentages of phosphorus which were not heretofore suitable for furnishing iron for the Bessemer process, may also permit the use of fuel which has heretofore been objectionable for the same reason, so that seams of coal which have been useless for this purpose may now be available.

My object has been more to call attention to the subject than to give the results I obtained in detail, and in this connection I submit the following abstract from a very interesting table, giving the percentages of forty specimens of bituminous coal from Western Pennsylvania by A. S. McCreath, Esq., of the Pennsylvania State Geological Survey, presented at the meeting of the American Institute of Mining Engineers this week, showing in one specimen as much as ·1667 per cent. of phosphorus in the coal, and ·2818 per cent. in the coke made from it:

		pr. ct. in Coal.	pr. ct. in Coke.
Washington county,	maximum	·1667	·2818
" "	minimum	·0011	·0018
Green "	maximum	·0053	·0084
" "	minimum	·0025	·0041
Westmoreland county,	maximum	·0801	·1177
" "	minimum	trace.	trace.
Fayette county,	maximum	·0111	·0164
" "	minimum	trace.	trace.
Somerset "	maximum	·0105	·0135
" "	minimum	·0058	·0074
Beaver "	maximum	·0058	·0094
" "	minimum	trace.	trace.
Cambria "	maximum	·0530	·0638
" "	minimum	trace.	trace.
Blair "	maximum	·0075	·0103
" "	minimum	trace.	trace.
Clearfield county,	maximum minimum	·0080	·0107
Huntington "	maximum	·0080	0093
" "	minimum	trace.	trace.

During the past nine years Dr. C. M. Cresson has been employed by the Philadelphia & Reading Railroad and Philadelphia & Reading Coal & Iron Company in making analyses of coals from their numerous collieries. Many of these examinations have included complete sections of the whole vein, including the slates; others are of large samples of coals, weighing several hundred pounds each, and taken from the schutes from which it is about to be shipped to market. I am also in receipt of a letter from Dr. Cresson, intended to be read at the meeting of the American Institute of Mining Engineers at Pittsburgh, on the same subject, and also in reference to some recent examinations which he has made.

417 WALNUT STREET, PHILADELPHIA, May 14th, 1879.

W. E. C. COXE, Esq.—

DEAR SIR:—By reference, I find that the announcement that the slates accompanying anthracites frequently contained phosphorus, as well as sulphur was made at the meetings of the American Philosophical Society, held May 1st, 1874, and March 5th, 1875. The major part of the phosphorus is in the upper slate, and varying amounts have been got from the dividing and lower slates. I have found that the sulphur is generally distributed and located in a similar manner. A knowledge of these facts enables the selection of anthracite with a minimum both of sulphur and of phosphorus. In fact, the competition for trade has rendered such careful preparation necessary, and there are now mined and sent to market, from Schulkill county, coals practically free from both phosphorus and sulphur. I have recently made analyses of large samples taken from the cars as they were loaded for market at the Boston Run and Hammond collieries of the Philadelphia and Reading Coal and Iron Company, and find that they do not contain an appreciable amount of phosphorus and of sulphur but 0·1233 per cent. and 0·0822 per cent., respectively. You will perceive, therefore, that the substitution of coke, either in whole or in part, as suggested for properly prepared coals will not improve upon the quality of these coals in respect to the elements named.

Respectfully, CHARLES M. CRESSON, M.D.

THE REACTION PRINCIPLE OF DYNAMO-ELECTRIC MACHINES.

By Profs. Edwin J. Houston and Elihu Thomson.

The honor of the discovery of the reaction principle of dynamo-electric machines is very generally accredited, as independent inventions, to Siemens, Wheatstone and Varley, but accorded by priority of publication to Siemens.

The idea of applying currents, generated by a magneto-electric machine, to the strengthening of its own magnets, appears to have been discovered as early as 1855, as will be seen.

It appears from the records of the British Patents that one Soren Hjorth, of Copenhagen, filed an application for letters patent for the invention of "An improved electric battery," as he styled it. The application was sealed the 28th of September, 1855, and dated April 11th, 1855.

The following quotations from the completed specification will suffice to show the nature of the invention.

* * * "Various attempts have been made to produce electricity by means of armatures brought in succession within the action of permanent magnets. Now my invention consists in certain improved arrangements for producing electricity in great quantity and intensity by these means. For this purpose, a series of armatures on a wheel revolving at a slow motion are brought in succession between the poles of permanent magnets and the poles of a series of electro-magnets surrounded with spiral rings or coils of copper." * * *

"The action of the battery is as follows: The permanent magnets acting on the armatures brought in succession between their poles induce a current in the coils of the armatures, which current, after having been caused by the commutator to flow in one direction, passes around the electro-magnets, charging the same and acting on the armatures. By the mutual action between the electro-magnets and the armatures an oscillating force is obtained which, in the result, produces electricity greater in quantity and intensity than has hitherto been obtained by any similar means."

After the above, the step towards the use of electro-magnets only, which retain a slight amount of residual magnetism, as is now common, was but slight; hence the honor of the discovery needs still further division.

Central High School, Philadelphia, June 4, 1879.

REPORT ON THE EXPERIMENTS WITH THE ELECTRIC LIGHT ON THE VICTORIA EMBANKMENT, LONDON.

The joint official report of Sir J. W. Bazalgette, the engineer, and Mr. T. W. Keates, the consulting chemist of the Metropolitan Board of Works, has recently been made public, and is a model of what such a report should be.

For the first time in the history of the electric light, as applied to street illumination, we have a series of data laid before us about whose accuracy there can be no doubt. Hitherto such reports have emanated from either gas-managers or electricians, whose interests—wrongly we think—have been held to be opposed to each other; hence the singular discrepancies in the data which have been issued up to the present time. It must be perfectly understood that we in no way intend to make the slightest imputation against the honor of the authors of these reports; but when one side tells us that the electric light is cheaper than gas, and the other that gas is cheaper than the electric light, we can only account for the discordance of opinion by supposing that the reporters' judgment must have been unconsciously influenced by their anterior convictions. In the present instance we have the conclusions of two eminent public officials, who have no other interests to serve than those of the community at large, and who are wholly independent of the advocates or opponents of either system of lighting.

We regret that we cannot follow the reporters through all the elaborate series of calculations which they have laid before us; we can only gather a few of the results of their carefully conducted experiments. One great point which has been decided on the Victoria Embankment is that the steadiness of the light is in a great measure dependent on the regularity with which the motive power is supplied to the electric machine. In the present case this uniformity of power was secured by the use of a specially constructed 20 horse-power engine, provided with an automatic governor of extraordinary sensi-

tiveness, the whole being supplied gratuitously for three months by Messrs. Ransomes, Sims, and Head, of Ipswich.

The experiments upon which Messrs. Bazalgette and Keates' figures are founded began on January 24th, and were continued until February 5th, Sundays excepted,—or, in other words, for twelve nights,—the engine being driven for 5·5 hours each night, the whole 26 lamps being lighted. The mean daily cost of working the engine, including wages, was found to be £1 9s. 8½d., or 3·24d. per lamp per hour. The cost of the whole plant was £1280, but a smaller engine would be quite sufficient for the purpose; the capital required, therefore, might be reduced to £990.

"The accurate estimation of the amount of light given off by the electric arc and ignited carbons is," say the reporters, "a matter of great difficulty, so much so that the best results which have been obtained can only be looked upon as fairly approximating to the truth." This difficulty arises from two causes; first, from the difference in color between the electric light and any standard of light at our command; and secondly, the fluctuating character of the electric light. The photometrical experiments made on the Embankment were—1st, on the naked light; 2dly, on a light with a opaline globe, and 3dly, on a light with a granulated globe. The measurements were made with an ordinary bar photometer, fitted with a movable screen with a star disk.

The standard unit of light which was used was a sperm oil lamp, specially constructed for the purpose by Mr. Sugg, and fitted to the photometer by a peculiar balance, by which the necessity for removing the lamp during the course of any number of experiments is obviated. The unit of light given by this lamp was equal to 16 Parliamentary standard sperm candles. Twenty readings were made on each experiment, both with open and shaded lights,—that is to say, 160 on the naked light, 24 with the opaline globe, and 16 with the granulated globe. The following are the mean results obtained in these experiments:—

Naked light . . .	378·1	sperm candles.
Opaline globe . .	154·9	" "
Granulated globe . .	265·0	" "

The loss of light produced by the opaline globes is 59 per cent.; by the granulated globes, 29·9 per cent.

Taking the above data as approximately correct, the gross output of light from the twenty Jablochkoff candles amounts to 7562 candles, nearly 60 per cent. of which is absorbed at once by the opal globes. There are also two other sources of loss: first, from the greater thickness of the opal glass in the lower third of the globes; and secondly, from the fact that the most favorable direction for the projection of the light from the Jablochkoff candle is upwards, there being an actual diminution of light horizontally, and still more so downwards.

On the 14th and 15th of March a very important experiment was made, with a view of ascertaining whether the circuits could be increased in length to a considerable degree without diminishing the apparent value of the lights on such circuits. The Westminster and Waterloo circuits—that is to say, the two at each end of the line—were thrown into one, the total length of the wire being 7063 feet, three of the lights being at the Westminster end and the other two at the Waterloo end. The lights burned with apparently equal brilliancy as when short-circuited, and on the following day the length of the line was increased to 8815 feet, or 1·66 mile, but still without any perceptible effect on the light. We believe this is the longest circuit ever attempted to be used with an alternating current machine, and the success of the experiment has a very important bearing on the general question of electric lighting.

We have said before that the cost of a plant necessary for working twenty Jablochkoff lights is £990. The interest on this at 5 per cent. would be £49 10s., and taking wear and tear at 10 per cent., £99, we get a total of £148 10s. Taking the whole time during which the lamps are lighted in the year at 3600 hours, say 10 hours a day, the cost of use of plant for each light per hour is 0·49d. To this we must add 3·24d. per light per hour for the cost of producing the light, and 2d. per hour per candle, making a total of 5·73d. per light per hour all the year round. Let us now compare the cost of gas with the latter figure. The light in the opal globe, as given above, is in round numbers equal to 155 candles, and in the granulated globe to 265 candles. To produce a light equal to 125 candles, one of the larger Sugg burners consumes 48 cubic feet of gas per hour, while to produce a 265-candle light we should require 83 cubic feet per hour. The cost of the former quantity of gas may be taken at 2d., of the latter at 3·5d., or, to put the matter more plainly,

The cost of the electric light is . .	5·73 per hour.
Gas equivalent to electric light in opal globe,	2·00 "
" " " frosted " .	3·50 "

We have therefore, at last, a series of figures on this important subject which cannot possibly be doubted. The experiments which have yielded them have been carried out with the greatest care, and every precaution has been taken to render them so correct that all future cavil or controversy will be avoided; the practical outcome of the matter being that, used in the best possible manner, the amount of illumination in both cases being equal, the electric light costs $1\frac{2}{3}$ times as much as gas.

Sir William Thomson gave some valuable evidence on Friday before the Select Committee engaged in considering the subject of the electric light. He said that whereas one horse-power of energy would only produce 12-candle gas light, it might produce 2400-candle electric light. "The upshot of the experiments made at the factory of Messrs. Siemens, at Woolwich, and at the natural philosophy class of the University of Edinburgh, was that, allowing the practical estimate of one horse-power applied in driving the engine, it had produced 1200 candles of actual visible electric light, half the gross energy going to produce the light while the other half was lost in heating the machine and the wires. As the electric light was such an economical producer he anticipated that it had a great and immediate future before it. He believed before long it would be used in every case where a fixed light was required, whether in large rooms or small ones—even in passages and staircases of private dwellings. There was immense promise in the actual work carried out by practical men in the present day. There was a prodigiously greater economy in the transmission of mechanical force into energy in the case of the electric light than in the case of gas. With regard to regulators for the electric light, he had seen one the previous day—the Siemens regulator—which gave a steady, pure and quiet light. The electric light was especially adapted for being placed high where it illuminated a wide area. It might be put upon an iron pole raised 60 feet high, or the old French plan of swinging a lamp on a wire from one side of the street to the other might be followed with advantage. Such a plan would be useful in doing away with the necessity for opal globes, which destroyed a large quantity of the illuminating quality of the light. Indeed, he was surprised that these globes had ever been used, wasting as they did 50 or 60 per cent. of

the illuminating power. He considered that the advantages of using the electric light within buildings would be very great, because of the small effect it would have when compared with gas in heating and vitiating the atmosphere. In the case of electricity, the waves of light only became converted into sensible heat, not in the air, but on the ceiling or walls and floor of the room after they had done their work. With regard to the subdivision of the light, according to practical experiments, if the same amount of energy that was used in producing one large light was employed in producing ten feebler lights, none of those lights gave one-tenth of the amount of illumination of the one large concentrated light. Still there was nothing mathematically impossible in the matter, and it was quite possible that a plan of subdivision might be found by which the ten feebler lights would give a sum of illumination equal to that of the one larger light. He considered that the electric light as now developed was fit for use in large rooms."

A Fatal Colliery.—In a recent explosion of fire-damp, in the Agrappe mine, near Mons, 147 lives were destroyed. Thirty years ago, in an explosion which was caused by the imprudence and obstinacy of some of the workmen, 750 men were lost. Four years ago, 118 miners were killed in the same shaft, and work was resumed in it only two months before this third fatal explosion.—*La Nature.* C.

The Longest Tunnel in the World.—Notwithstanding the magnitude of the St. Gothard Tunnel, its length is not so great as that of the gallery of the Joseph II. mine, in the Hungarian valley of the Grau. It was begun in 1782, to drain the mines of Schemnitz, and has been continued, with many interruptions, until its recent completion. The Sutro Tunnel is 6147 metres (3·82 miles) long; the Mont Cenis, 12,233 metres (7·6 miles); the St. Gothard, 14,920 metres (9·27 miles); the Joseph II., 16,538 metres (10·28 miles). The total cost of the last tunnel has been 11,497,500 francs ($2,299,500). It is of great geological value; it has opened a new region of rich mining property; it has supplanted all the pumping engines, thereby effecting an annual saving of $50,000; it has opened the way for the employment of new inventions and new methods of working which will render all the tributary mines more productive and more profitable.—*La Nature.* C.

Artificial Lithographic Stone.—A. Regel, of Gotha, has found that artificial plates of Portland cement may be used with advantage in lithography as a substitute for the costly Sohrhofen stone.—*Dingler's Journal.* C.

Hydraulic Tubing.—G. Parravicini recommends a more general substitution of terra cotta and cement tubes for those of brick and stone, in sewers, water-ways and other similar underground structures. Among the advantages which he enumerates are: 1, Reduced cost of foundations; 2, Ease of building in running water; 3, Saving of time in construction; 4, Possibility of carrying on the work in winter and at other times when labor is cheap.—*Il Politecnico.* C.

Steamship Improvement.—It is interesting to compare the present performance of the transatlantic steamers, and their relative consumption of coal, with the same data in 1840. The *Britannic*, of the White Star Line, made average passages in the year 1877 in 7 days 10 hours and 53 minutes, consuming less than 250 kilogrammes (551·155 lbs.) of coal for 1000 kilogrammes of freight, and having an average speed of 15·6 knots per hour. On the other hand, in 1840 the *Britannia*, the most famous steamer of its day, used 2400 kilogrammes (5291·091 lbs.) of coal per 1000 kilogrammes of freight, with an average velocity of only 8½ knots per hour.—*Fortschr. der Zeit.* C.

Unity of Geological Forces.—W. H. Herncite explains the great differences in the figures of the planets, by the combined action of centrifugal force and the distribution of solar heat. Mars, for example, is flattened at the poles by a percentage which is nine times as great as that of the Earth, although the ratio of the centrifugal force to gravitation is nearly the same in each of the two planets. In the Earth, the free circulation of the ocean waters makes the figure of the globe nearly the same as if it was entirely liquid. But in Mars the oceans are mostly of a Mediterranean character, so that the equatorial expansion by heat and the polar expansion by cold produce an increased relative polar compression. Herncite gives reasons for thinking that the play of volcanic forces has been of much less importance than has been commonly imagined. He examines especially the theory that volcanos act as safety-valves, and finds that, for such a purpose, each volcanic chimney should have an area of more than a square kilometre. (1093623·11 square yards).—*Les Mondes.* C.

Comparative Strength of Wood and Iron.—Heim finds that, in most cases, a uniform strength of structure can be more economically secured by the use of wood than by the use of iron. The strength of wood is proportioned to its density, and can be increased by its immersion for two or three days, or until complete saturation, in linseed oil, kept at a temperature of from 150° to 212° Fahr.—*Fortschr. der Zeit.* C.

Artificial Imitation of Native Iron.—S. Meunier has confirmed his theory in regard to the terrestrial origin of the supposed meteoric native iron of Greenland, by the action of protochloride of iron and chloride of nickel upon fragments of iron in a porcelain tube. He thus obtained a fac-simile, upon a microscopic scale, of the huge blocks which were brought from Disco by M. Nordenskjold.—*Comptes Rendus.* C.

Relations of Fusion to Molecular Oscillation.—R. Pictet supposes that the temperature may be represented by the length of the calorific oscillation of the molecules of a body, and from this hypothesis he deduces the two following laws: 1. The higher the melting point of a solid, the shorter are the molecular oscillations. 2. The products of the temperatures of fusion by the lengths of oscillation, are constant for all solids. The laws are confirmed by all the metals of which the coefficients of dilation have been determined with sufficient accuracy. Similar relations hold good for the elements of volatile liquids, when they are compared at their boiling points. These laws may be classed with the law of constancy between the products of atomic weights and specific heats.—*Comptes Rendus.* C.

Microphonic Study.—Boudet de Paris has experimented with a microphonic transmitter, in which the carbons, instead of being pressed by a spring, are simply kept in contact by a bit of paper folded like a V. It was so sensitive that, with a single Leclanché cell, and at a distance of 500 metres (1640·4 feet), the receiving telephone reproduced the message so that it could be heard in all parts of the hall. By increasing the amplitude of the vibrations he found that they were of two kinds: 1. Large vibrations, or rather undulations, which always occurred in the same order for any given word or vowel. 2. Small vibrations, very short, very numerous, looped upon the larger ones. He thinks that the undulations are due either to the force of the breath which necessarily accompanies the emission of the voice, or to the inertia of the instrument.—*Comptes Rendus.* C.

Artificial Ultramarine.—This product has almost wholly supplanted the cobalt dyes, and it has largely taken the place of Prussian and other blues. In 1862 the total production was 3556 tons; in 1872 it had risen to 8585 tons, exclusive of the amounts manufactured in an English and in an American factory. The present product is probably over 12,000 tons. The materials employed in the manufacture are sulphide of sodium, sulphate and carbonate of soda, sulphur, carbon and silicates of alumina.—*La Gaceta Indust.* C.

Franklin Institute.

HALL OF THE INSTITUTE, June 18th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 137 members and 93 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that, at the last meeting, 11 persons were elected members of the Institute, and reported also the following donations to the Library:

Eighth Annual Report of the Board of Regents of the Smithsonian Institution. From the Institution.

First to Fourth Catalogues of the Central University, Richmond, Ky. From Prof. Tobin.

Programme of the Seventh Annual Exhibition in Chicago. From the Exposition Company.

Industrial Art Education. By W. Smith. From the Author.

Third Report of the New York State Survey. From James T. Gardner, Director.

Ninth Report of the Board of Trustees of the Illinois Industrial University. From the Board.

Seventh Report of the Board of Directors of the Zoological Society of Philadelphia. From the Society.

Great Blast at Glenton. By Ellis Clark, Jr. From the Author.

Report of Permanent Committee of the First International Congress at Vienna.
From the Meteorological Committee of the Royal Society, London.

Mercantile Library. Finding List. From the Library.

Lists of Beacons, Buoys, etc., in the Light House Districts.
Annual Reports of the Light House Board.
Experiments on Babbage's Method of Distinguishing Light Houses.
Compilation of Public Documents and Extracts from Reports and Papers Relating to Light Houses.
List of Lights on the Northern Lake and River Coasts of the United States.
Specifications, etc., for Light Houses at Thirty-mile Point, N. Y., Hilton Head Range, Fort Ripley Shoal, etc.
Light House Papers.
Laws Relating to the Acquisition of Title to Land Required for Light House Purposes.
Laws of the United States relating to the Establishment, Support, etc., of Light Houses, Vessels, etc.
Extracts from Report of Her Brittannic Majesty's Commission Appointed to Inquire into the Condition, etc., of Lights, Buoys and Beacons.
List of Light Houses, Lighted Beacons, etc., on the Atlantic, Gulf and Pacific Coasts of the United States.
Charts showing Positions, Range, etc., of Lights in Light Houses on the Coast.
Plans, Drawings, etc., of Light Houses, Buoys, Fog-whistles, etc.
From the Light House Board.

Ninth Report of the President and Directors of the Lake Shore and Michigan Southern Railway Company. From the Company.

Revised Regulations for the Government of the Life-saving Service.
Reports of the Operations of the Life-saving Service.
From the Life-saving Bureau, Washington.

Report of the Superintendent of the Seventh Census.
From the Census Bureau.

Useful Information Pertaining to the Generation and Use of Steam. By Babcock & Wilcox, New York. From the Authors.

Pottery and Porcelain at the Paris Exposition.
From J. E. Caldwell & Co., Philadelphia.

Quarterly Report of the Chief of the Bureau of Statistics.
From the Chief of Bureau, Washington.

Notes on the Life and Character of Joseph Henry. By James C. Welling. Philadelphia. From the Author.

Graphical Method for Finding the Real Roots of Numerical Equations of any Degree. By W. H. Hunt.
From W. H. Bixby, New York.

Annual Report of the Secretary of the American Iron and Steel Association.

Proceedings of the Convention of Iron and Steel Manufacturers and Iron Ore Producers, held at Pittsburg.
From the American Iron and Steel Association.

Report on the Bridging of the Mississippi River. By G. K. Warren. From the Chief of Engineers.

Documents Relative to the Origin and History of the Smithsonian Institution. By W. J. Rhees. From the Institution.

Specifications and Drawings of Patents issued from the United States Patent Office, for January and February, 1879.
From the Patent Office.

Annual Report of the Chief Signal Officer to the Secretary of War.
From A. J. Meyer, Chief Signal Officer.

Alphabetical Index of Patents and Applicants for Patents of Invention. From the Commissioners of Patents, London.

Report on Safety-valve Tests made at the United States Navy Yard, Washington.

Iron Manufactures in Great Britain. By R. H. Thurston.

Annual Report of Chief of Bureau of Steam Engineering.

Report of the Board to Recommend a Standard Gauge for Bolts, Nuts, etc., for U. S. Navy.

Report on the Herreshoff Boiler, submitted to the Navy Department.

Report on the Ashcroft Furnace-doors and Grate-bars.

Report on the Murphy Grate-bar.

Report on the Two Kinds of Coal Submitted by the Chesapeake & Ohio Railroad Coal Agency.

Register of the Commissioned, etc., Officers of the Navy of the United States, including Officers of the Marine Corps.
From Chief Engineer Fitch.

Resources of the United States for Sheep Husbandry and the Wool Manufacture. By J. L. Hayes.

Sheep Husbandry in the South. By J. L. Hayes.

American Textile Machinery. do.

Protective Question Abroad. do.

Protective Question at Home. do.

Notes upon Indigo. do.

Tariff Policy of England and of the United States Contrasted. By E. B. Bigelow.

Awards and Claims of Exhibitors at the International Exhibition.

Bulletin of the National Association of Wool Manufacturers. Vol. 5 to Vol. 9.

Directory of the United States Textile Manufacturers.
From the National Association of Wool Manufacturers.

Report of the Commission on Site for Naval Observatory. Washington.

Investigation of Corrections to Hansen's Tables of the Moon. By S. Newcomb. Washington.

Report on the Difference of Longitude between Washington and Detroit, Mich., etc. By J. R. Eastman. Washington.

Report on the Difference of Longitude between Washington and St. Louis. By Wm. Harkness. Washington.

Report on the Difference of Longitude between Washington and Ogden, Utah. By J. K. Eastman. Washington.

Meteorological Observations made at the United States Naval Observatory. Washington.

Tables of Instrumental Constants and Corrections for the Reduction of Transit Observations made at the U. S. Naval Observatory. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Meridian Circle.

Uranian and Neptunian Systems Investigated with the 26-inch Equatorial of the United States Naval Observatory. By Simon Newcomb. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Meridian Transit Instrument. Washington.

Zones of Stars Observed at the United States Naval Observatory with the Mural Circle. Washington.
From Prof. E. S. Holden, Librarian U. S. Naval Observatory.

Papers relating to the Foreign Relations of the United States. Washington.

Annual Reports upon the Commercial Relations of the United States with Foreign Countries. From the Secretary of State.

The Secretary read a memorial of Dr. Hays, prepared by Mr. Frederick Fraley, chairman of the committee appointed on the subject,

which, on motion of Mr. Orr, was ordered to be published in the JOURNAL.

MEMORIAL OF DR. ISAAC HAYS.

By the death of Dr. ISAAC HAYS the Franklin Institute has lost one of its original members, who for many years of its early history and labors occupied a prominent official position. Born in the city of Philadelphia of most respectable lineage, educated in her best schools and in the University of Pennsylvania, he was prepared by these advantages to occupy prominent positions and to participate in great public concerns. His career was one of great usefulness, and his services to the Institute were of great value. He knew its founders and original members well—they were endeared to him by ties formed in youth, which were strengthened by years and by congenial tastes and labors. In the profession of medicine he soon attained high rank, and his reputation for skill was of universal acceptance. As a member and officer of the American Philosophical Society, of the Academy of Natural Sciences, and other institutions, he was constantly engaged in scientific labors and in the pursuit of useful knowledge. As the life-long editor of the oldest and best medical serial in the United States, he was the means of diffusing most widely all the results of medical experience and practice, and he thus became medically known throughout the world as an able and distinguished man. For many years he devoted himself to the relief of the blind, and of those suffering from diseases of the eye in Wills Hospital, and these services, rendered without compensation, are among the evidences of his enlarged philanthropy. He thus fulfilled all the duties of a man and a citizen with great ability and faithfulness, and finally sank to his rest, after reaching upwards of four score years, crowned with the respect and honors of his fellow-citizens. While we mourn his loss we are thankful that he was spared to us so long for an example, and we pay this tribute to his memory in the hope that in the future many may be induced to emulate his worth, and in their day and generation to be as useful and worthy as he was.

Mr. Henry Bentley read the paper announced for the evening, on "Electro-chemical or Loud-speaking Telephones," and the large audience present had the opportunity of hearing the instrument for the first time in this country, and noticing the wonderful clearness of the speech uttered and the various airs, played at a distance.

After a discussion of the subject by Mr. Nystrom, Dr. Rogers and Mr. Orr, Mr. Roberts moved that a vote of thanks be tendered to Mr. Edison and to Mr. Bentley for the great pleasure given by them, and that the Secretary transmit a copy, which was unanimously carried.

Mr. George Burnham, Jr., made some remarks on a new Casting

Cleaning Brush as applied to the Stow Flexible Shaft, and the instrument was shown in operation. Mr. Richards and Mr. Eldridge spoke on the subject.

Mr. Richards explained an improvement on his Measuring Machines, devised by Mr. George Richards, and which adds little to the cost.

The Secretary exhibited one of Grossmann's Micrometers, the outside circle graduated in hundredths of a millimetre and the inside in thousandths of an inch, as well as a large model of a lever escapement; inserted teeth for circular saws; a new insulating material of cork and paper pulp; a new Algerian paper stock; an oiler for a loose pulley as used in France; a specimen of a square hole drilled in a piece of brass with a triangular rotating drill and French printed matches made with an automatic machine from a round block of wood.

A letter from Mr. Van Allen was read, describing the method of drilling holes only the one-hundredth of an inch in pieces of osmiridium, as devised by Mr. John Holland, of Cincinnati, for the Mackinnon Fountain Pen.

Sharpened copper shafts of the required diameter are made to revolve at the rate of about five thousand revolutions a minute. The particles of osmiridium are soldered to a brass plate and the holes started with a diamond drill. These holes are then gradually deepened till cut through, by touching them to the revolving copper shafts.

Turkish emery and oil are the only assistants. As the shafts are quickly dulled, they are as speedily sharpened, while in motion, by a touch of the file.

The Secretary read an account of Harrington's Screw Hoisting Machines, and a large model was also shown, also the Blacklock Fan Attachment for Sewing Machines.

Mr. Moore exhibited and described his Sanitary Closet, and the subject was discussed by Mr. Ware and Dr. Rogers.

Mr. Lance described his new method of propelling boats by air, a small model being shown. Mr. Jones spoke on the subject.

Mr. Jones announced the death of Mr. William Adamson, and offered the following resolution, which was adopted:

Resolved, That a committee be appointed by the President to prepare a memorial of our late fellow-member.

On motion, the meeting adjourned until the third Wednesday in September.

ISAAC NORRIS, M. D., *Secretary pro tem.*

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3. The Board of Managers of the Franklin Institute shall, before the first day of January, one thousand eight hundred and eighty-one select three citizens of the United States, of competent scientific ability, to whom the memoir shall be referred; and the said Judges shall examine the memoirs and report to the Franklin Institute whether, in their opinion, and, if so, which of their memoirs is worthy of the premium. And, on their report, the Franklin Institute shall decide whether the premium shall be awarded as recommended by the Judges.

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